HOUSE OF COMMONS
CHAMBRE DES COMMUNES
CANADA

INQUIRY OF MINISTRY
DEMANDE DE RENSEIGNEMENT AU GOUVERNEMENT

PREPARE IN ENGLISH AND FRENCH MARKING "ORIGINAL TEXT" OR "TRANSLATION"
PRÉPARER EN ANGLAIS ET EN FRANÇAIS EN INDIQUANT "TEXTE ORIGINAL" OU "TRADUCTION"

QUESTION NO./Nº DE LA QUESTION	BY / DE	DATE
Q-1012	Mr. Nater (Perth-Wellington)	May 1, 2017

Reply by the Minister of Environment and Climate Change
Réponse de la ministre de l'Environnement et du Changement climatique

The Honourable Catherine McKenna

PRINT NAME OF SIGNATORY
INSCRIRE LE NOM DU SIGNATAIRE

SIGNATURE
MINISTER OR PARLIAMENTARY SECRETARY
MINISTRE OU SECRÉTAIRE PARLEMENTAIRE

QUESTION

With regard to Budget 2017 and to contracts signed by the government with McKinsey and Company, its partners or consultants, since November 4, 2015, for each contract: (*a*) what is the (i) value, (ii) description of the service provided, (iii) date and duration, (iv) internal tracking or file number; (*b*) was the contract sole sourced; (*c*) what specific role did McKinsey and Company, its partners or consultants, or Dominic Barton play in the preparation of Budget 2017; (*d*) what specific sections of Budget 2017 were prepared by, in whole or in part, by McKinsey and Company, its partners or consultants; and (*e*) what are the details of any briefing notes or memorandums regarding Budget 2017, McKinsey and Company, its partners or consultants, or Dominic Barton, including for each the (i) sender, (ii) recipients, (iii) title and subject matter, (iv) date, (v) internal file or tracking number?

REPLY / RÉPONSE

ORIGINAL TEXT / TEXTE ORIGINAL: X — TRANSLATION / TRADUCTION: ☐

ENVIRONMENT AND CLIMATE CHANGE CANADA

Environment and Climate Change Canada has no contracts awarded in relation to (a), (b) and (e) in Q-1012.

CANADIAN ENVIRONMENTAL ASSESSMENT AGENCY

The Canadian Environmental Assessment Agency has no contracts awarded since November 4, 2015 in relation to (a), (b) and (e) in Q-1012.

PARKS CANADA

Parks Canada has no contracts awarded since November 4, 2015 in relation to (a), (b) and (e) in Q-1012.

.../2

CHAMBRE DES COMMUNES
HOUSE OF COMMONS
CANADA

INQUIRY OF MINISTRY
DEMANDE DE RENSEIGNEMENT AU GOUVERNEMENT

PREPARE IN ENGLISH AND FRENCH MARKING "ORIGINAL TEXT" OR "TRANSLATION"
PRÉPARER EN ANGLAIS ET EN FRANÇAIS EN INDIQUANT "TEXTE ORIGINAL" OU "TRADUCTION"

QUESTION NO./Nº DE LA QUESTION	BY / DE	DATE
Q-1012	M. Nater (Perth-Wellington)	Le 1er mai 2017

Reply by the Minister of Environment and Climate Change
Réponse de la ministre de l'Environnement et du Changement climatique

L'honorable Catherine McKenna

PRINT NAME OF SIGNATORY
INSCRIRE LE NOM DU SIGNATAIRE

SIGNATURE
MINISTER OR PARLIAMENTARY SECRETARY
MINISTRE OU SECRÉTAIRE PARLEMENTAIRE

QUESTION

En ce qui concerne le budget de 2017 et les contrats que le gouvernement a signés avec McKinsey and Company, ses partenaires ou experts-conseils, depuis le 4 novembre 2015, pour chaque contrat : *a*) quel est (i) la valeur, (ii) la description du service rendu, (iii) la date et la durée, (iv) le numéro de suivi ou de dossier interne; *b*) s'agissait-il d'un contrat à fournisseur unique; *c*) quel rôle précis McKinsey and Company, ses partenaires ou experts-conseils, ou Dominic Barton ont-ils joué dans la production du budget de 2017; *d*) quelles sections du budget de 2017 ont été produites, en tout ou en partie, par McKinsey and Company, ses partenaires ou ses experts-conseils; *e*) quels sont les détails de toutes notes d'information ou notes de service concernant le budget de 2017, McKinsey and Company, ses partenaires ou experts-conseils, ou Dominic Barton, y compris, pour chacune, (i) l'expéditeur, (ii) les destinataires, (iii) le titre et l'objet, (iv) la date, (v) le numéro de suivi ou de dossier interne?

REPLY / RÉPONSE

ORIGINAL TEXT / TEXTE ORIGINAL [ ]   TRANSLATION / TRADUCTION [x]

ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA

Environnement et Changement climatique Canada n'a aucun contrat accordé en ce qui concerne a), b) et e) dans Q-1012.

AGENCE CANADIENNE D'ÉVALUATION ENVIRONNEMENTALE

L'Agence canadienne d'évaluation environnementale n'a aucun contrat accordé depuis le 4 novembre 2015 en ce qui concerne a), b) et e) dans Q-1012.

PARCS CANADA

Parcs Canada n'a aucun contrat accordé depuis le 4 novembre 2015 en ce qui concerne a), b) et e) dans Q-1012.

.../2

Name of organization
Corporate Services and Finance Branch

STATEMENT OF COMPLETENESS

RESPONSE TO WRITTEN QUESTION, Q-1012

Name of Parliamentarian : Mr. Nater Constituency: Perth-Wellington
Date of Inquiry: May 1, 2017

A) 1. Briefly describe records, analysis and consultations on which the proposed response is based:

A search has been conducted of the Department's Financial System from November 4th, 2015 to May 1st, 2017. As a result, there were no contracts identified with either Dominic Barton or McKinsey and Company for that specified period.

As per the instructions from PCO, the search was limited to contracts awarded to McKinsey and Company and Dominic Barton as the reference to partners and consultants is too vague.

Lead official: Alain Marcotte

2. Were publicly available documents used to draft the response? If yes, please list titles and dates below:

Yes [ ] No [X]

B) Describe any limitations, considerations and/ or data quality statements that apply to this response:

Yes [ ] No [X]

Canada

C) Have information or documents relevant to this response been disclosed publicly, in any manner (e.g. access to information request or request from the Library of Parliament)? If yes, please identify relevant documents and explain any differences in the proposed response.

Yes	N/A
	X

Attestation:

As the Designated Senior Official for **(Corporate Services and Finance Branch)** I attest that the information contained in the proposed response Q-1012, based on the records and limitations described in this Statement of Completeness, is accurate and as complete as possible.

s.19(1)

Signature

May 19 2017
Date

Carol Najm	ADM, Corporate Services and Finance Branch, Chief Financial Officer
Name of Designated Senior Official	Title

Canada

Name of organization
Canadian Environmental Assessment Agency

STATEMENT OF COMPLETENESS

RESPONSE TO WRITTEN QUESTION, Q-1012

Name of Parliamentarian : Mr. Nater Constituency: Perth-Wellington
Date of Inquiry: May 1, 2017

A) 1. Briefly describe records, analysis and consultations on which the proposed response is based:

A search has been conducted of the Canadian Environmental Assessment Agency's financial system from November 4, 2015 to May 1, 2017. There were no contracts with McKinsey and Company during this period. The translation was done internally. The answer for this written question took 1 hour to process.
Lead official: Danielle Laverdure

2. Were publicly available documents used to draft the response? If yes, please list titles and dates below:

Yes	No
	X

B) Describe any limitations, considerations and/ or data quality statements that apply to this response:

Yes	No
	X

Canada

C) Have information or documents relevant to this response been disclosed publicly, in any manner (e.g. access to information request or request from the Library of Parliament)? If yes, please identify relevant documents and explain any differences in the proposed response.

Yes	N/A
[ ]	[X]

Attestation:

As the Designated Senior Official for the Canadian Environmental Assessment Agency I attest that the information contained in the proposed response Q-1012, based on the records and limitations described in this Statement of Completeness, is accurate and as complete as possible.

s.19(1)

Signature ________ Date 11 May 17

Ron Hallman	President
Name of Designated Senior Official	Title

Canada

Name of organization
Parks Canada

STATEMENT OF COMPLETENESS

RESPONSE TO WRITTEN QUESTION, Q-1012

Name of Parliamentarian : Mr. Nater Constituency: Perth-Wellington
Date of Inquiry: May 1, 2017

A) 1. Briefly describe records, analysis and consultations on which the proposed response is based:

A search of Parks Canada's departmental financial system was undertaken for contracts with McKinsey and Company during the period of the request.

There were no contracts identified during the search.

Time spent to respond: 1 hour 45 minutes

Translation completed in house

Lead official: Sylvain Michaud

2. Were publicly available documents used to draft the response? If yes, please list titles and dates below:

Yes	No
	X

B) Describe any limitations, considerations and/ or data quality statements that apply to this response:

Yes	No
	X

C) Have information or documents relevant to this response been disclosed publicly, in any manner (e.g. access to information request or request from the Library of Parliament)? If yes, please identify relevant documents and explain any differences in the proposed response.

Yes	N/A
	X

Attestation:

As the Designated Senior Official for **Parks Canada**
I attest that the information contained in the proposed response Q-1012, based on the records and limitations described in this Statement of Completeness, is accurate and as complete as possible.

s.19(1)

Signature

10/5/17
Date

Sylvain Michaud	Chief Financial Officer
Name of Designated Senior Official	Title

Canada

Environment Canada / Environnement Canada

JAN 28 2016

MIN-196908

MEMORANDUM TO MINISTER

2012 MCKINSEY & COMPANY REPORT: OPPORTUNITIES FOR CANADIAN ENERGY TECHNOLOGIES IN GLOBAL MARKETS

(For Information)

PURPOSE

To provide you with a summary of a 2012 report on economic opportunities for energy technologies developed in Canada.

SUMMARY

- In 2012, Natural Resources Canada commissioned McKinsey & Company to analyze 24 clean energy technology areas in order to assess where Canada has an advantage or could build a sustainable advantage in global markets.

- The report identified significant near-term opportunities for Canada in four technology area clusters (unconventional oil and gas; next-generation transportation; energy efficiency; and distributed power generation) and longer term opportunities in a fifth cluster comprising carbon capture, biofuels, and fuel cell systems.

- For each cluster, the report suggests that government efforts could create stronger domestic demand through policy measures/incentives; provide additional support to exporting companies; coordinate provincial and federal financing vehicles to address a broader range of opportunities; ensure access to talent; and create a coordinated network of government institutions to support technology developers.

- Activities within the Department directly related to technology development include:
  - funding to and oversight of Sustainable Development Technology Canada (SDTC) to support clean technology development and demonstration;
  - oversight of the Environmental Technology Verification (ETV) program, which provides independent verification of environmental performance claims of technologies; and
  - policy and regulatory measures which serve as drivers.

- A potential area for further engagement by the Department in the Canadian innovation system is through environmental policy and regulatory development that provides an incentive for clean technology development (e.g., emissions regulations and other instruments under the *Canadian Environmental Protection Act, 1999*).

- No communications materials are required, as this is an overview of a report in the public domain commissioned by Natural Resources Canada. No stakeholder reaction is anticipated, as the report was made available in 2013.

CONTEXT

In 2012, Natural Resources Canada commissioned McKinsey & Company to analyze 24 clean energy technology areas in order to assess where Canada has an advantage or could build a sustainable advantage in global markets in the near future. These technology areas are of potential importance to Canada, given global energy demand and supply trends, the technologies that are anticipated to have significant value and impact on a global scale, and the technologies that could be considered strategic, given Canada's resources and assets.

SUMMARY OF FINDINGS

The report assesses the technology areas on the basis of:

1. global market attractiveness (market characteristics and attractiveness, including an evaluation of market size, growth, and structure, the role of technology along the value chain, and additional risks and challenges); and
2. Canada's competitiveness in the market (the existing advantage held by Canadian industry and any sustainable advantage that could be developed in the future).

The study recommendations centre on the identification of five clusters where McKinsey & Company sees significant opportunity and a role for government action and the identification of the policy mechanisms of highest potential.

1. **Unconventional oil and gas**: the study recommends that Canadian governments sustain Canada's advantage in unconventional oil and gas by fostering collaboration across the industry, by developing regulations/standards to spur domestic innovation, and by providing more economic incentives to the industry (e.g., lower royalties, risk-sharing, "prizes").

2. **Next-generation transportation**: the study recommends that Canadian governments cultivate leadership in next-generation transport by developing regulations/standards on fuel efficiency, rare earth mining, and compressed natural gas/liquefied natural gas; by providing incentives to automobile suppliers; by fostering collaboration across industry; by investing in plug-in hybrid electric vehicle infrastructure; and by educating and informing fleet owners about the benefits of adopting compressed natural gas/liquefied natural gas.

3. **Energy efficiency**: the study recommends that Canadian governments cultivate Canadian leadership in energy efficiency technologies by developing regulations/standards to spur innovation, by educating and informing the public about the benefits of energy efficiency, by investing in public buildings and government research, and by providing incentives to the industry (e.g., interest-free loans, share energy savings, pay back capital expenditures). The authors also recommend fostering collaboration between utilities and industry players to encourage adoption of energy-efficient water treatment technologies.

4. **Distributed power generation**: the study recommends that Canadian governments support select distributed power generation technologies based on risk/reward calculations. The report recommends providing direct investments and financial incentives to unconventional hydro, bioenergy, waste-to-energy, and solar energy technologies.

5. **Technologies with long-term potential**: The study recommends that Canadian governments wait for key developments before investing in technologies with potential longer term impact. Examples provided include carbon capture and storage, fuel cell systems, bio-refineries, and biofuels.

Recommended government action falls into six general categories, several of which relate to or have the potential to relate to activities in the Department. The Department would have an active role in three:

1. direct investment (funding for research, development, and demonstration (RD&D)) (through the Department's financial contribution to Sustainable Development Technology Canada);
2. infrastructure investment (through the Department's oversight of the Green Municipal Fund);
3. standards and regulations (through application of instruments under the *Canadian Environmental Protection Act, 1999*);
4. incentives and financing (to help generate demand);
5. greater collaboration; and
6. education and information.

In addition, the report recommends that the federal government complement its approach by providing the necessary conditions to create an enabling economic environment by creating stronger domestic demand through policy measures; providing additional support to exporting companies; coordinating provincial and federal financing vehicles to address a broader range of opportunities; ensuring access to talent; and creating a coordinated network of government institutions to support technology developers.

CONCLUSIONS
This memo is based on the Department's review of the report conducted in 2013.
No communications materials are required, as the report was publicly released by Natural Resources Canada in 2013. No adverse reaction from stakeholders to the report has been noted.

Michael Martin	Siddika Mithani
Deputy Minister	Associate Deputy Minister
c.c. Siddika Mithani	c.c. Michael Martin

Attachments (2):

- *Opportunities for Canadian energy technologies in global markets (final report), McKinsey & Company – November 19, 2012*
- *Opportunities for Canadian energy technologies in global markets (presentation), McKinsey & Company – November 19, 2012*

Drafting Officer's Name: Logan Leduc
Directorate/ Branch: STSD / S&T
Phone No: 819-938-3447
Date Drafted: January 4, 2016

Opportunities for Canadian energy technologies in global markets

Final Report

November 19, 2012

McKinsey&Company

Contents

Executive summary

Energy is vitally important to the Canadian economy – activity in the energy-related sector (fossil fuels, renewables and clean energy, distribution, buildings and communities, energy-intensive industrial processes, and transportation) generates more than $320 billion in GDP, approximately one-fifth of national GDP. Canada has a vast and diversified energy resource endowment and, through its open economy, the nation has become an important and reliable energy provider to the world. We are on the verge, however, of a massive innovation effort in global energy technologies across all energy-related supply, distribution, and demand sectors.

- Within energy supply, new oil and gas technologies will create access to previously inaccessible resources, while renewable sources of energy will increasingly be exploited as their cost (relative to traditional sources of energy) is reduced.
- Within energy distribution, smart grid technologies will integrate diverse energy sources (including renewables) and help monitor and reduce overall energy usage.
- Within energy demand, new energy-efficient technologies being created in anticipation of stricter emissions regulations are shaping industrial and commercial sectors, while fuel efficiency mandates are driving substitution in the transportation sectors.

In this context, governments around the world will be competing to capture value by exporting energy resources, by exporting energy technologies and services, and by increasing the competitiveness of their domestic industries through greater energy efficiencies and supplies of cheaper energy. As judged by the experience of other jurisdictions (i.e., Norway in oil and gas; and the United States' and Netherlands' focus on energy efficiency), nations that are successful in building competitiveness in energy sectors can increase their overall real GDP growth rate in these sectors by as much as 2 percent. For Canada, this would translate into $74 billion in incremental GDP by 2020, which translates into 500,000 jobs using sector by sector GDP to job ratios.

There is little doubt that governments will need to play an active role in capturing this value. Those developing energy technologies face unique challenges that are not always effectively resolved by market forces – most importantly, from the

Successful jurisdictions have taken two complementary approaches to supporting energy technologies. First, they have created an enabling environment that supports energy technology developers across all fields, encouraging the commercialization of new technologies and the scaling up of disruptive technologies. Second, they have provided targeted support to encourage competitiveness in priority technology areas – resolving market failures that government is uniquely positioned to address. This report provides Canadian-specific assessments on both of these dimensions.

CANADA COULD CREATE AN ENABLING ENVIRONMENT FOR ALL ENERGY TECHNOLOGY AREAS

The Canadian government could focus on four areas that would create a more enabling environment for all technology developers. (Please see the Potential government actions chapter for greater detail.)

Enable access to markets. Given energy technologies have long-term payout times, providing a stable domestic market (e.g., through time-phased domestic environmental standards) is important to encourage private investment. In addition, the energy technology export market is particularly important for Canada, given that its domestic energy market is relatively small and that relatively inexpensive electricity rates serve as a disincentive for domestic adoption of new technologies. Canadian governments could provide additional support to companies seeking to export energy technologies and services into price-competitive markets.

Enable access to capital. Canadian energy sectors face a scarcity of private funding and a poorly performing venture capital (VC) market. As part of a larger strategy to build a highly functioning Canadian venture capital community, Canadian governments need to remove contradictory incentives that impede energy technology developers attempting to access capital, and encourage collaboration between technology developers and capital financing.

Ensure access to talent. While Canada has world-class education systems, it still lacks skilled labour in select areas (e.g., oil sands operators, power plant engineers), which is made worse by the global brain drain. Canadian

governments could increase the supply of domestic talent by creating vocational/educational programs that serve energy technology developers. They could also help ensure that developers and startups are permitted to import the necessary skills when required.

Ensure effective coordination of government institutions. At the federal level, Canada has less government control of energy resources relative to other countries. Thus, to ensure high performance, it is imperative it foster a high level of coordination within the network of federal and provincial government institutions involved in supporting energy technology development.

PRIORITY TECHNOLOGY AREAS

To determine the priority areas, we first identified 14 technology areas that have a large global impact and value, excluding technology areas with small markets (less than $10 billion globally by 2020) or slow growth (less than 10 percent). Working with Canadian government and industry experts, we identified 10 additional technology areas that are strategically important to Canada.

We evaluated the potential economic impact and attractiveness of investing in each area, including global market size, growth, structure, and the role of technological innovation. We also evaluated whether Canada would have an advantage in the technology area, given the presence or absence of existing Canadian industry, assets, and intellectual property, Canada's natural resources, the Canadian regulatory environment, and socio-political factors. For priority technology areas, we identified specific barriers, focusing not on those barriers that market forces were already eroding, but instead on those that government is uniquely positioned to address. This exercise resulted in the identification of five clusters for potential government actions.

Unconventional oil and gas. Although Canadian industry leaders are already investing heavily in technology research, development, and demonstration (RD&D) in an effort to make these sectors competitive from a cost perspective, Canadian governments could help sustain the country's advantage in this area by providing incentives to spur the development of environmental technologies that will be crucial in establishing the social licence to operate. These actions will create value primarily by enabling the export of domestic oil and gas sources.

Next-generation transportation. As industry leaders invest heavily in RD&D related to electric vehicles (EV) and plug-in hybrid electric vehicle (PHEV)

components (in anticipation of tighter fuel efficiency standards), Canadian governments could introduce a combination of levers that ensure Canada continues to be a manufacturing hub and offer incentives for, or directly invest in, the creation of infrastructure that will enable adoption. By using the domestic market to build export capability, these actions create value primarily through the global export of manufactured automotive EV components and, secondarily, through fuel efficiency gains from the domestic adoption of technologies.

Energy efficiency technologies. In this area, the market is making some investment in technology development, but both adoption and development are slow because of market structure challenges. Canadian governments could drive innovation through education, incentives for early adoption, and/or by progressively tightening regulatory standards. These actions will create value by enabling the increased global competitiveness of energy-intensive Canadian industrial companies; secondarily, by using the domestic market to build the export capacity of energy-efficient building, industrial, or water technologies and services as they are developed; and, finally, by the savings for Canadian industrial consumers on their energy bills.

Distributed power generation. In this fast growing market, Canada is one of multiple countries engaged in technology development. Canadian governments could drive global competitiveness by selectively acting in sub-sectors where it feels it can create competitiveness. We offer a list of four distributed power generation technology areas where Canada has some advantage and potential to gain a substantial portion of global market. While each technology is slightly different, most of them could benefit from government assistance in either co-funding or fostering collaboration in pilots (e.g., securing a waste source for a waste-to-energy demonstration plant). In all cases, pilots would use the domestic market to build the export capacity of these technologies. This area offers high return potential – but also strong competition from foreign companies.

Potential longer-term opportunities. Carbon capture and storage (CCS), hydrogen fuel systems, and biorefinery/bioproducts all have strengths in Canada, but unpredictable market size and timing, driven by either regulatory or technology uncertainty. Given limited funds, the Canadian government could monitor key developments before investing (e.g., until an approximately $40 carbon price is ratified in major markets for CCS, major industry investment in fuel cell infrastructure and vehicles, and/or identification and scale-up of value-added biorefinery products from thermal or biochemical processes). Innovation

could also be sustained by funding "prizes" for disruptive breakthroughs in fundamental challenges, ensuring impactful investment.

Potential government actions

As successful jurisdictions have done, Canada could have an impact across all energy technologies, as well as in priority areas.

CANADA COULD CREATE AN ENABLING ENVIRONMENT FOR ALL ENERGY TECHNOLOGY AREAS

The Canadian government could take the following four approaches to create a more enabling environment for all technology developers. In each approach, we offer examples of other government actions.

Enable access to markets. To encourage stability in the domestic market, Canadian governments could use either regulations or incentives for target sectors. California has been exceptionally successful in using building efficiency codes to create a stable market for energy-efficient technologies, and grow domestic innovation that is exportable. A mechanism in the code lowers the standards as technologies enable greater and greater efficiencies, thereby encouraging continual innovation and providing reliable demand for companies. A similar effort to grow the US shale gas industry used a production tax credit to maintain a viable market as the technologies developed. The experiences of successful jurisdictions suggest that government policies can create reliable demand and a stable market, spurring innovation and industry development.

To enable domestic companies access to price-competitive foreign markets, Canadian governments could provide additional support for companies seeking to export energy technologies and services. The federal and provincial governments could sustain existing initiatives that support companies seeking to export energy technologies and services into price-competitive markets (e.g., the Trade Commission and the Export Development Canada – Sustainable Development Technology Canada partnership). Small technology start-ups in particular would benefit from government help in navigating international IP law, determining target costs, and connecting with international customers to set up technology demonstration projects. Israel offers several types of effective government assistance to exporting companies, such as establishing offices abroad that provide resources, contacts, and infrastructure, and facilitating visits by foreign stakeholders to tour Israeli industries. Similar to Israel, Canadian government agencies could facilitate connections between Canadian companies and potential foreign partner governments as well as enhance domestic resources to help

companies prepare strategies for export (e.g., helping startups establish export supply chains).

Enable access to capital. As part of a larger strategy to build a highly functioning Canadian VC community, Canadian governments need to ensure small companies are attracted to and incentivized to remain in Canada. To discourage premature technology sales and buy-outs, the federal government could increase access to capital for young companies that would otherwise need to sell intellectual property (IP) to maintain financial viability. A more stringent option for addressing premature exits would be imposing restrictions on government-funded startups, but the issue of limited capital would still need to be addressed.

Ensure access to talent. To ensure labour supply does not become a constraint to growth, the Canadian government could actively increase talent supply, both domestically and by importing talent. When Norway began developing its oil and gas sector, it identified the need for skilled workers and adjusted its education curriculum to produce domestic workers for the growing industry. Taiwan took additional steps, devoting an agency to bringing in foreign and expatriate talent for its blossoming semiconductor industry.

Similarly, Canadian provincial governments could increase the domestic talent supply by offering incentives for creating vocational/educational programs that serve the labour needs of energy technology developers. To help developers and startups bring in top foreign talent, the federal government could also use immigration incentives to attract energy technology experts.

Ensure effective coordination of government institutions. Canadian governments could strengthen their network of federal and provincial government institutions and government-industry networks with a common mandate to support energy technology developers. Other countries have found that their efforts to support industries are most effective when they are well coordinated and offer the needed support at each step along the innovation chain. For example, Singapore provided research funding and then implemented regulations that pulled innovations from the lab to the field, where a demand had been created. Finland used a slightly different approach to developing a broader set of technologies, creating an investment fund (known as SITRA) that provides capital to startups that may be too risky or unfamiliar for the private sector to fund. Taiwan used a third approach, establishing government-owned companies

to commercialize its emerging semiconductor technology and later privatizing the companies as they became economically sustainable.

Similarly, Canada's network of institutions could coordinate RD&D with standards/regulations. Government institutions could also set up co-funding programs and seed risk capital to help energy technology small and medium enterprises (SMEs) that have difficulty accessing capital. This network could then play a direct role in commercializing new technologies through public-private partnerships or government-owned entities.

PRIORITY TECHNOLOGY AREAS

In determining priority technology areas, our overall approach (Exhibit 1) was to examine globally attractive technology areas (Section A), and assess priority technology areas in which Canada has a competitive advantage.(Section B). For the priority technology areas, we identified specific barriers to development (Section C), focusing not on barriers subject to erosion by market forces but instead on those that the government is uniquely positioned to remove.

EXHIBIT 1

Overall project approach

	Section A	Section B	Section C
	▪ **Question A1** – What are the trends, risks, and opportunities in global energy demand and supply? ▪ **Question A2** – Given global energy demand/supply, what are the technologies likely to have a significant impact/value? ▪ **Question A3** – Given Canada's resources and assets, what additional technologies should be considered for strategic reasons?	▪ **Question B1** – What is the inherent attractiveness of the market (growth, size, maturity, role of technology)? ▪ **Question B2** – Does Canada have potential to compete and capture this value given its existing assets and capabilities? ▪ **Question B3** – Do other jurisdictions have clear advantages given existing assets and capabilities?	▪ **Question C1** – What are the key barriers facing priority technology areas? ▪ **Question C2** – For which of these barriers are government actions warranted (based on natural or unique ownership)? ▪ **Question C3** – What is currently being done by government to resolve these barriers? ▪ **Question C4** – What are the performance indicators that will be used to gauge the effectiveness of the actions?
Deliverable	List of globally attractive and strategically important technology areas	Specific assessment of market attractiveness to Canada, and our ability to compete	Perspective on what additional things can be done to: a) create a supportive environment for all technology developers; and b) resolve specific barriers related to prioritized technology areas

As shown in Exhibit 2, government actions fall broadly into six categories: direct investment (e.g., funding technology RD&D directly), infrastructure investment, incentives and financing (e.g. helping generate technology demand and adoption), standards and regulations, education and information, and greater collaboration. For each of the barriers, we suggest options for potential government actions, incorporating previous successful Canadian government actions and best practices from other jurisdictions. In emerging and longer-term technology areas, we highlight potential rewards and risks, as well as the key indicators to monitor market conditions that signal further large-scale investment.

EXHIBIT 2

There are six categories of levers that government can use to help remove the barriers to improving Canadian technology competitiveness

	Examples
Direct investment	• Government labs; grants for research, development, and demonstration; provision of risk capital for technology commercialization • Provision of capital for pilots or deployment, including procurement (e.g., piloting leading-edge efficiency tech in government buildings)
Incentives & financing	• Low-interest loans to stimulate demand for technology adoption • Tariffs or tax breaks related to technology adoption
Infrastructure investment	• Physical infrastructure investments to enable specific industries (e.g., charging stations for EV)
Standards and regulations	• Performance standards, potentially with disincentives • Licenses & permits • IP protection laws
Education and information	• Providing monitoring data to end users • Consumer labeling (e.g., Energy Star) • Investments in labor capabilities and capacity to enable an industry (e.g., building education capacity for researchers and field workers)
Foster collaboration	• Establishment of national vision and strategy • Network building and connection of stakeholders • Multi-lateral offerings (e.g., utility-funded installation of home energy efficiency tech by private company)

McKinsey & Company | 14

After assessing the barriers and appropriate levers, the priority technologies fell into one of five investment clusters:

- Sustain advantage on unconventional oil and gas
- Cultivate Canadian leadership in next-generation transport
- Cultivate Canadian leadership in energy-efficient technologies
- Support select distributed power-generation technologies based on risk/reward calculations

- Wait for key developments before further large-scale investment in technologies with potential longer-term impact.

These clusters, their sub-technology areas, barriers to growth, and government-specific levers are described below.

Sustain advantage on unconventional oil and gas

Unconventional oil and gas, water treatment, air quality, and land remediation

Barrier. Improving the performance of environmental technologies is essential to maintaining the social licence to operate and for broad exportability (e.g., certain regions have banned fracking for shale gas). Although new environmental technologies exist at small scales, industry has been stalling full-scale pilots until regulations are mandated and enforced. Without full-scale pilots, oil and gas majors are reluctant to adopt the new technologies.

Highest-potential levers and rationale. Governments could foster collaboration across potentially competitive companies to facilitate the transfer of environmental technologies within industries. Continuing to support consortiums and shared research centres (e.g., recent Alberta provincial commitments to environmental technology development) could help reduce the cost base across industrial players. Longer term, governments can also put in place phased environmental regulations. Despite likely industry resistance, phased regulations that stay ahead of global trends have proven successful in spurring domestic innovation elsewhere. For example, Singapore's push to advance its water management used regulations to develop the country into an innovation hub for water treatment technologies. Advanced regulations are already occurring in shale gas in Canada, and successful environmental monitoring partnerships between Ottawa and Alberta have helped, but federal incentive is needed to encourage industry support. Once developed, environmental technologies can be exported globally to other regions or industries. As an alternative option to regulations, governments could offer private sector firms a variety of incentives such as reduced provincial royalties and risk-sharing and government prizes for public or private research laboratories solutions to solve fundamental technology challenges (e.g., steam to oil ratio in oil sands). Advanced environmental technologies will be important in the 2020 time frame for Canadian global technology competitiveness and maintaining a social licence to operate in unconventional oil and gas.

Unconventional oil drilling and extraction technologies

Barrier. To maintain Canada's advantage long term by tapping into currently uneconomic unconventional oil resources, it is important to lower the costs of drilling and extraction. Although oil companies are already investing in new oil drilling and extraction technologies, operators face a tradeoff of piloting new techniques versus immediate production, even though at-scale pilots are essential before adoption.

Highest-potential levers and rationale. Canadian governments could foster **collaboration** between technology holders and oil majors or help form a consortium between oil majors (e.g., Norway's licences for oil and gas exploitation encouraged strategic collaborations and joint ventures between companies). In addition, Canadian governments could also provide private sector firms with incentives such as reduced royalties and risk-sharing. The US government, for example, fuelled its shale gas boom in part through its involvement in demonstration projects and offering tax incentives for investment.

Cultivate Canadian leadership in next-generation transport

Next-generation auto adoption (e.g. hybrid and electric)

Barrier. Although industry is already investing in batteries, advanced internal combustion engines (ICEs), and lightweight vehicles, the Canadian government could accelerate adoption by helping lower costs through achieving scale.

Highest-potential levers and rationale. If Canadian governments set fuel efficiency regulations that are more advanced and aggressive than those of the United States and the European Union, it could cement Canada's role as a pilot site for new technologies (similar to the way the European Union's fuel efficiency standards have driven domestic innovation without major government financial contribution.

Next-generation auto infrastructure

Barrier. Today, manufacturers are deferring infrastructure investment until the demand is greater. Adoption is even slower given the uncertainty in charging standards and technological advancement, and the competition among manufacturers.

Highest-potential levers and rationale. By investing in infrastructure (either directly or in coordination with private sector firms), Canada could become an

early leader, attracting foreign investment for pilots and then developing innovation and export capabilities. Notably, some provincial governments have already made initial investments in infrastructure pilot projects (e.g., Ontario-Québec partnership for EV charging infrastructure), but collaboration at the federal level would boost support and help drive Canadian competitiveness in both infrastructure innovation and domestic adoption. Canadian governments could also foster collaboration among industry players to drive the adoption of a cost-effective unified charging standard (similar to Portugal's efforts to create a nationwide charging infrastructure with universal access and streamlined payment) and enable the innovation and export of Canadian infrastructure technologies/services.

Next-generation auto e-motors hub

Barrier. Electric motors are a crucial component in PHEVs, and rare-earth magnets are a crucial cost component for electric motors. Today, China has become a global leader of e-motor manufacturing and technology by establishing a low-cost rare-earth supply. Vehicle original equipment manufacturers (OEMs) are concerned by this lack of competition, particularly because other countries have become reluctant to invest in rare-earth mining.

Highest-potential levers and rationale. If Canada wants to compete successfully with China and be another e-motor hub, it will require a suite of measures to increase Canada's cost competitiveness (similar to Taiwan's investment in research, infrastructure, and subsidies to support its semiconductor industry and Denmark's investments to support its wind energy industry). Canadian governments could invest in infrastructure near rare-earth deposits in Canada to attract domestic mining companies. This would entice foreign OEMs to participate in an e-motor hub in Canada (e.g., tax advantages and reduced infrastructure costs). In addition Canadian governments could foster collaboration among mining companies, auto suppliers, and OEMs to create an e-motor innovation and manufacturing hub in Canada. Brazil used similar techniques – establishing refining and feedstock infrastructure and coordinating the actions of many industry stakeholders – to develop its ethanol industry.

Natural gas fleet adoption

Barrier. Due to the recent boom in natural gas (NG) production in North America, we expect domestic gas prices to stay low through at least 2030 (competitive with diesel as vehicle fuel). Still, fleet owners are reluctant to pay the vehicle premium due to risk aversion and previous poor experience with NG

price volatility. Further, adoption is slowed by the lack of compressed natural gas and liquefied natural gas (CNG/LNG) codes and standards, as well as a lack of infrastructure, which is a bigger concern for long-haul fleets.

Highest-potential levers and rationale. Given that the United States will be the largest CNG/LNG fleet market, Canada could harmonize its standards and infrastructure with the United States to enable the export of technologies and services and help domestic NG engine technology companies thrive. In addition, Canadian governments could help educate and inform fleet owners about the cost benefits of CNG/LNG adoption for domestic adoption.

Cultivate Canadian leadership in energy-efficient technologies

Energy-efficient (EE) buildings/industrials technology adoption

Barrier. Although many technologies are economically attractive, builders and industrial players are risk averse, focus on short-term returns, lack capital, and have limited awareness of energy efficiency gains. Misaligned incentives can also stifle adoption of economically attractive technologies (e.g., when installing an energy-efficient air conditioner, a builder or owner might pay for the upfront cost, but a renter gets the benefits).

Highest-potential levers and rationale. Staged regulations are the most powerful tool for Canadian governments (particularly for buildings, as illustrated by California's successful example), but education and incentives are also useful levers for early adopters. For example, the Netherlands runs a successful industrial efficiency program that educates and enables companies to implement efficiency technologies. It offers free energy audits and assistance in planning efficiency upgrades and monitoring progress. On the incentives side, Austria has been successful in promoting the use of bioheat/power by establishing a favourable tax structure for wood fuel pellets (in conjunction with education and regulations). Canada already has had impressive achievements (e.g., ecoENERGY program) but could co-ordinate with provincial efforts (e.g., equipment standards, building codes, utility regulation and revenue decoupling, energy audits, and efficiency upgrades). In addition, the Canadian government could create further incentives targeted to industrials (e.g., interest-free loans, sharing energy savings to pay back capex).

EE buildings/industrials new technology development

Barrier. While some energy-intensive industrial sectors are investing in RD&D for new technologies, the development of disruptive technologies is slow in some areas. Additionally, small innovative companies have difficulty attracting funding for early development and pilots. For example, many building markets are cost-driven and companies lack the capital to invest in disruptive RD&D or the talent to be successful.

Highest-potential levers and rationale. As a result of a shortage of RD&D talent in small companies, the Canadian government needs to continue to directly invest in the short term by conducting research in government institutes. To transition into long-term private sector investment, the government could invest in education and vocation programs to build up talent capacity (similar to Norway's adaption of its education system to train locals in the skills needed for the emerging oil and gas industry), as well as implement phased regulations (as in California).

Water utility adoption of EE technologies

Barrier. Water utilities are risk averse and slow to adopt new technologies, preferring to defer large capital investments and favouring local contracts with which they have prior experience.

Highest-potential levers and rationale. Given the strong presence of water treatment companies in Canada, the Canadian government could use regulations to drive innovation and sustain its advantage (similar to how Singapore's advanced regulations have made it an innovation hub). Strengthening Canadian water regulations and standards could spur domestic innovation in low-cost technologies and attract investment in pilots. In addition, Canadian governments could foster collaboration between utilities and industry players to encourage early adoption.

Support select distributed power-generation technologies based on risk/reward calculations

Distributed power generation is a fast growing market where Canada is one of multiple countries engaged in technology development. Canada's opportunity lies in driving global competitiveness by selectively investing in subsectors where it feels it can create an advantage.

Unconventional hydro (e.g., in-river hydrokinetic turbines) has large global potential, and Canada has strong domestic resources and some emerging potential technology leaders.

Barrier. Currently, Canadian startups need help with larger scale commercial pilots to demonstrate the reliability of emerging technologies.

Highest-potential levers and rationale. Canadian governments could help by investing directly in commercial-scale pilots for low-head river projects in the near term and creating price guarantees or favourable feed-in tarrifs (FIT) for excess electricity to stimulate domestic adoption. Canadian governments could monitor the competitive landscape and the risk of copying, as well as the threat of a foreign purchase of Canadian IP before the technology developed from that IP could bring economic benefit to Canada.

Bioenergy (electricity and heat from biomass) is expected to be high growth in the EU, driven by its 2020 renewable targets and leading to an attractive equipment export market, particularly for easier to export small-scale plants.

Barrier. Canada has some leadership in combined heat and power (CHP) from the pulp and paper industry and from related innovations. While large-scale plant technology is relatively mature and similar to coal-fired plants, Canadian companies need small-scale pilot opportunities to advance CHP technology along the learning and cost curve.

Highest-potential levers and rationale. Canadian governments could support technology development through direct investment in the production of commercial-scale pilots for CHP plant adoption in favourable locations across Canada. In addition, Canadian governments could monitor international regulations for bioenergy (since it is not necessarily economic without regulatory support) as well as the development of the competing technology in the European Union.

Waste-to-Energy (WTE – municipal solid waste conversion to energy) has llarge untapped global potential, driven by high urban density and tipping fees in the United States and the European Union.

Barrier. While Canada has potential technology leaders in its startups, they are having trouble sourcing feedstock for WTE plants given the unwillingness of utilities to enter into new contracts requiring further waste stream processing.

Highest-potential levers and rationale. Canadian governments can offer incentives to municipal utilities to ensure feedstock availability for WTE start-ups, but it would be economically difficult in Canada given lower tipping fees and cheaper electricity, than in the major EU market. Even if technologies are established, there is still a risk of foreign purchase of Canadian IP before manufacturing and supply chains are built up in Canada.

Solar photovoltaic (PV) off-grid has a large market potential, particularly in emerging economies with solar resources (e.g., India).

Barrier. Canada has some startups and a major solar PV company, but these companies need pilots to demonstrate off-grid solar PV technologies and to reduce costs for export markets.

Highest-potential levers and rationale. The Canadian government can directly invest in developing domestic off-grid solar PV pilots and offer communities incentives to participate in them, but this will be challenging given Canada's limited solar resources, particularly in off-grid regions. Additionally, Chinese companies may focus on off-grid PV given that they have already invested significantly in PV manufacturing capacity.

Wait for key developments before further large-scale investment in technologies with potential longer-term impact

Several longer-term technologies, including carbon capture and storage (CCS), hydrogen fuel systems, and biorefinery/bioproducts have uncertain market size and timing, driven by either regulatory or technology concerns. Given limited funds, the Canadian government would benefit from monitoring key developments in these markets before taking a further risk with heavy investment. Innovation could also be spurred with government-sponsored "prizes" for public or private laboratories for breakthroughs in fundamental scientific problems, ensuring investment is tied to success.

Carbon capture and storage

Barrier. Current CCS technologies are not economic without high CO_2 prices ($40 to $50 range), leading to uncertainty around the timing and size of the market.

Highest-potential levers and rationale. Canadian governments could monitor the market's development. The key indicators include: the United States or China

making a significant commitment to mandatory carbon pricing (around $40 to $50); or the industry making a significant contribution to CCS or GHG abatement and/or volunteering to reduce emissions in an effort to maintain its social licence to operate. Once there are positive signs in the market, Canadian governments could provide direct investment in RD&D and pilots (in addition to existing investments in R&D, pilots such as Quest, etc.) related to the capture and sequestration of technologies. In addition, Canadian governments could establish regulations and standards related to carbon accounting and sequestration liability, incentivizing domestic adoption.

Hydrogen fuel systems

Barrier. Existing technologies are not cost-effective without higher fuel efficiency standards, and there is a "chicken and egg" challenge in infrastructure investment.

Highest-potential levers and rationale. Canadian governments could monitor the market and technology developments for signals such as a breakthrough in catalyst research, a major player investing in infrastructure, or a major OEM placing a large bet on hydrogen. Once there are positive signs in the market and for the technology, Canadian governments could continue investments (such as R&D at the National Research Council or universities) and could incentivize foreign investment (similar to what Daimler has already done in Vancouver), as well as provide direct investment for fuel cell technology RD&D and infrastructure.

Biofuels/biorefinery

Barrier. The market for biorefinery products is unclear and the products themselves are not yet well defined. Additionally, the cost of lignocellulosic biofuel technologies is high compared with other second-generation biofuels.

Highest-potential levers and rationale. Canadian governments could monitor the market and technology developments, looking for a major government (or private corporation with global scale) to mandate the use of bio-plastics or other bio products or a breakthrough in the cost position of lignocellulosic technologies. Once there are positive signs in the market and for the technology, Canadian governments could continue investments (such as the SDTC next-generation biofuel fund) and could provide further direct investment in RD&D, as well as offer incentives for biorefinery investment through long-term biomass feedstock contracts.

Overall, this study examined Canada's investment profile in energy technologies, where growing markets will be in 2020, what Canada's advantage in these markets are, and where policies might be effective in removing barriers that are preventing Canadian growth in these areas. Looking forward, beyond policies that overcome specific barriers, Canada could create a strategic national program to encourage investments, incentives, and growth in energy technologies. By prioritizing, setting discrete goals, and measuring desired metrics (e.g., GDP impact, job growth, IP filings, VC investment, level of risk), Canada could continue to make informed decisions on investments in energy technologies. Leveraging the advanced education and entrepreneurial spirit of Canadians, along with providing incentives to avoid the frustrations of technological "valleys of death," Canada could maintain a top position as an energy producer and secure a future as a global hub for the development and growth of energy technologies.

Resources used at each stage

We used several McKinsey, Canadian government, and external resources at every stage of the process, as shown in Exhibit 3. To validate our findings, we also consulted numerous McKinsey, Canadian government, and industry sources. A complete list of interviews is provided in Appendix 1: Sources.

EXHIBIT 3

Resources used at each stage

Section A	Section B	Section C
McKinsey resources ▪ Resource Revolutions Report ▪ Carbon Abatement Curve ▪ Global Energy Perspective (GEP) Model ▪ Expert interviews with internal tech experts **Other resources** ▪ Input from NRCan technology experts ▪ Market research and government sector reports	**McKinsey resources** ▪ Technology area specific analysis from EPNG[1] and SRP[1] Practices ▪ Expert interviews with internal tech experts ▪ Cleantech fund database **Other resources** ▪ Feedback from Environment Canada, Industry Canada, SDTC,[2] and NRCan ▪ SDTC investment database ▪ RD&D company database ▪ Market research and government sector reports ▪ Company and industry association reports ▪ Venture capital reports	**McKinsey resources** ▪ Expert interviews with McKinsey policy and innovation experts ▪ Previous policy studies by the Public Sector Practice **Other resources** ▪ Reports: Jenkins, Mowat Centre; Business Development Canada (BDC); NRCan; Canada Foundation for Innovation; Science, Technology and Innovation Council; Council of Canadian Academies; GLOBE: National Angel Organization; Deloitte & Deloitte ▪ Venture capital firms

Deliverable	List of globally attractive and strategically important technology areas	Specific assessment of market attractiveness to Canada, and our ability to compete	Perspective on what additional things can be done to: a) create a supportive environment for all technology developers; and b) resolve specific barriers related to prioritized technology areas

1 EPNG: Electric Power and Natural Gas; SRP: Sustainability and Resource Productivity
2 SDTC: Sustainable Development Technology Canada

Section A: An initial list of potentially attractive technologies

SECTION A1: GLOBAL ENERGY SECTOR TRENDS, RISKS, AND OPPORTUNITIES

In the next 40 years, the world will see the emergence of 3 billion middle-class consumers. The demands of these consumers for vehicles, consumer products, water, housing, buildings, and services will drive far-reaching searches for new sources of energy: petroleum, renewable energy sources, energy-efficient vehicles, buildings, industrial processes, efficient methods of generating and distributing electrical power, and more.

It is impossible to predict the exact course of the technologies and markets that will serve these demands. We have, however, assembled what we understand about today's major technologies – their costs, growth, and productivity trends across regions – and assumptions about future energy regulations into a model of how the global energy landscape might evolve over the next 40 years.

This work, published in the *Resource Revolution* report, used in McKinsey's Global Energy Perspective model and Carbon Abatement Curve, and detailed in Appendix 2, outlines several trends across the fossil fuel, renewable, industrial, and transportation energy sectors.

- Coal will be the major fuel for power generation in Asia, and natural gas will grow in prominence in the United States and Canada. Growth in total energy demand in the United States and Canada will be modest or falling, driven by the increased adoption of energy-efficient transportation and industrial processes.
- Growth in renewables will be strong. Biomass will have the highest growth rate in the European Union by 2020. After 2030, global growth in renewables will be led by wind and solar globally. Demand for nuclear is declining in the United States, the European Union, and Japan, but will remain strong in China and India. Hydroelectric power will continue to dominate Canadian power generation in the long term.
- For industrial processes, growth will be strongest in the chemicals sectors, driven by high demand in Asia. In comparison, demand for chemicals in Canada and the United States will be modest or flat. Demand in the building

- The global light vehicle mix will shift to plug-in hybrid electric vehicles (PHEV) in 2030 and beyond, with predominantly PHEV in the Canadian and US markets and a larger battery-powered electric vehicle (BEV) market in China. The number of vehicles sold will increase dramatically in Asia, while growth will be modest elsewhere. In the United States, the heavy truck mix will shift to a natural gas-powered vehicle as a result of low natural gas prices.

Many of the technologies under consideration, such as Renewable Energy Source (RES) adoption, carbon capture and sequestration (CCS), and electric vehicle (EV) transport mixes, depend on the regulatory environment (e.g., carbon pricing and government mandates) and details of oil and gas price assumptions. We used the McKinsey Global Energy Perspective (GEP) model to test the sensitivity of these predictions to assumptions about Canadian oil prices, rates of technology adoption, and carbon regulations, as described in Appendix 2. Although there is some predictable dependence on these factors (e.g., increased CCS adoption in China and the United States under higher carbon prices), overall trends are not strongly dependent upon regulatory assumptions, particularly through 2020.

SECTION A2: TECHNOLOGIES LIKELY TO HAVE SIGNIFICANT IMPACT AND VALUE

Work by McKinsey's Sustainability and Resource Productivity (SRP) Practice has identified 14 energy-related technologies that are poised to create a large-scale impact in the global economy (Table 1).

Table 1 – 14 globally attractive technology areas

	Technology area	Technologies under consideration	Market attractiveness and drivers
Fossil fuels	**Unconventional gas**	Shale gas extraction, supply chain and field management, gas to liquid, and liquid natural gas technologies	Unconventional gas will be 30% of North American gas production by 2020 due to improved extraction technology, causing flat natural gas prices

	Technology area	Technologies under consideration	Market attractiveness and drivers
	Unconventional oil	Bitumen extraction, upgrade, water treatment, pipelines	In 2020, there will be a ~$100 billion market for oil sands capital expenditure (capex) and revenue due to improved extraction techniques and rising conventional oil prices. (Unconventional oil is only attractive at high oil prices, which are expected to continue.)
Renewable and clean energy	**Solar PV**	Poly-Silicon to Photo-voltaic (PV) module value chain, balance of system, end applications	The worldwide PV modules market will be $325 billion by 2020 and $962 billion by 2030, driven by new applications and decreases in PV module price.
	Wind	Wind turbine generator (WTG) components, manufacturing, and operation	The WTG market will be $680 billion by 2020 with increases in reliability, efficiency, and cost-effectiveness driving worldwide adoption.
	Bioenergy	Biomass collection and processing, bioheat, biopower, CHP (combined heat and power)	By 2020, there will be $200 billion in capex, mostly in EU markets and driven by regulatory requirements.
	Biofuels	Production of biodiesel, bioethanol, other second-generation biofuels, and biorefinery products	Cellulosic biofuel demand in 2020 will be 64 GL, and 400 new plants will be built for cellulosic biofuels alone. Markets will be driven by regulations, subsidies, strategic considerations (e.g., jet biofuels), and the low cost of first-generation bioethanol.
Distribution	**Smart grid**	Metering, grid storage, network, demand management/response, appliances, software and integration, transmission and distribution (T&D) components, renewables integration	The market in 2011 for hardware and software will be $41 billion, and growth will be driven by increased utility adoption. A 2020 market of $10 billion for T&D components will be driven by utility adoption of more efficient, reliable, and controllable power electronic components.
Buildings and communities	**Energy- efficient buildings**	Advanced windows value chain, heating and cooling value chain, system integration, prefab houses	The building sector accounts for 30% of energy use today, and 2011 markets were large for windows ($69 billion) and heating and cooling ($130 billion). Strict regulations will drive higher efficiency in new construction and retrofits.
	Advanced lighting	Light-emitting diode (LED) lighting (semiconductor, packaging, luminaire, control)	A 2020 market of $38 billion for LED lighting will be driven by bans on incandescents and a decrease in the cost of LEDs.

	Technology area	Technologies under consideration	Market attractiveness and drivers
Energy-intensive industrial processes	**Waste to energy**	Equipment, design and engineering, construction	In 2014, revenue will be $4 billion and the equipment market will be $77 billion. EU markets will be driven by tipping fees and a phase-out of landfills.
	Water	Water-treatment equipment, operation and maintenance, consumer and commercial products	The 2011 global market was $515 billion ($110 billion for equipment). Growth will be driven by pressure on water supplies from increases in population and industrial/ mining/extraction demand.
	Energy- efficient industrial processes	Industrial process optimization	Industry accounts for 32% of energy use today; disruptive technologies can cut energy use in half and reduce emissions.
	Compressed natural gas (CNG) and liquefied natural gas (LNG) fleets	Natural gas engines and refueling infrastructure	By 2020, 20% of heavy vehicles in North America will be CNG/LNG, spurred by low natural gas prices.
Trans-portation	**Next-generation auto**	Internal combustion engine technology, regenerative braking, lightweighting, batteries, motors, charging infrastructure	The market penetration for PHEV will be $22 million by 2020 and $87 million by 2050, with increasing battery-powered electric vehicle (BEV) and fuel cell vehicle (FCV) adoption in China.

These technologies were chosen on the basis of several common features that ensure their eventual rapid adoption: 1) they are backwards compatible with existing infrastructure or products; 2) they have a clear path to good or excellent performance when compared to existing products; 3) they accomplish this high performance using less energy or waste; and 4) they are ultimately less expensive than existing products. In many cases, the markets for these technologies are also large (greater than $10 billion in many cases) and fast-growing (greater than 2 to 5 percent per year for larger markets and greater than 5 to 10 percent for smaller markets).

The chosen technologies can create value for Canada in three ways: 1) by enabling commodities like oil and gas to be extracted and exported at low cost; 2) by creating products or services to be exported to global markets; and 3) by lowering the domestic cost of energy production and usage. Most technology areas create value in more than one way. For instance, unconventional oil and gas technologies primarily enable the export of inexpensive Canadian fossil fuels, but

they also have potentially exportable services, such as water and tailings management. Similarly, next-generation automobiles offer domestic benefits from efficiency gains along with export opportunities for the technologies. To evaluate how individual technologies might create value for Canada, we identified the components in each technology's value chain that will be most important for development and growth in global markets. For each component, we consulted expert sources to better understand the specific technological challenges and business models. We focused on the role of technological innovation in the market (i.e., whether it is in the form of incremental decreases in cost or as a disruptive innovation) and the market structure (e.g., whether the market contains a few dominant global companies or many small regional companies), as well as Canada's competitiveness in that component.

The 14 technology areas cover a range of markets of varying size and maturity. In Section B, we evaluate the technologies' potential market sizes and attractiveness using McKinsey's GEP model, expert interviews, and market reports. We also assess the markets' accessibility to global and Canadian companies and their potential for large-scale manufacturing, export, and import.

Technology areas we excluded from consideration include:

- Large markets with slow growth, mature technologies, and established global companies, such as conventional oil and gas, conventional coal, and oil-and-gas distribution with the exception of pipelines, gas-to-liquid (GTL), liquid natural gas (LNG), and gasification technologies.
- Niche technologies and markets (such as airborne wind turbines and osmotic hydropower) that tend to be small and immature (less than $10 billion in size by 2020). There are often several potential technological winners – increasing the risk that a substitute can be found – and in many cases, the potential product is based on a single technology that could be easily copied and produced elsewhere. Exceptions include CCS and hydrogen fuel cells because of the large existing Canadian investment and potential long-term impact.
- Areas not directly related to energy generation, distribution, or efficiency (e.g., water-efficient agriculture, chemical processes, electronic waste recycling). Although these processes affect energy usage in many cases, it is a secondary effect. One notable exception is water treatment and purification technology. In this technology area, energy expenditures are sometimes high (e.g., desalination) and, in many cases, closely tied to oil and gas production.

SECTION A3: ADDITIONAL TECHNOLOGY AREAS WITH STRATEGIC IMPORTANCE TO CANADA

Although several of the 14 technologies listed in the previous section are strategic to Canada, additional technologies are worth evaluating because of their importance to Canada, even if they are less globally attractive. After discussions with experts at Natural Resources Canada (NRCan), we included 10 additional areas that are important to Canada for strategic reasons beyond just market size and growth (Table 2).

Table 2 – Ten additional areas were assessed for market size, growth, technology maturity, and drivers

	Technology area	Technologies under consideration	Market size and drivers
Fossil fuels	**Enhanced HC recovery**	Enhanced oil recovery (EOR) and coal bed methane (CBM)	The 2011 market was $36 billion from Canada's EOR revenue and global capex, driven by higher oil prices.
	CCS	Carbon capture, coal and natural gas CCS, CO_2 transport and storage	CCS could offset oil sands CO_2 costs, depending on CO_2 price acceptance in the EU and China. Slow growth is expected until after 2030 and, by 2050, capex spend on gas and coal CCS is expected to be $230 billion.
	Gasification	Gasification of coal or biogas into syngas or fuel	Canada has large coal and biomass resources. There is a $4 billion global equipment market, mostly driven by China.
Renewable energy sources	**Uranium**	Uranium mining	The 2020 markets will be $14 billion for mining and $10 billion for enrichment. Canada has the second largest reserves and a top uranium miner (Cameco).
	Nuclear technologies	Uranium enrichment, traditional reactors, nuclear fusion, small-scale	45-50GW to retire/refurbish by 2050, several are CANDU designs serviceable by CAD; 400-500 billion new builds primarily in China and India. Long-term potential in fusion and small-scale.
	Geothermal	Power generation (equipment, engineering, project management), CHP	Canada has a large, untapped geothermal potential. There is a $3 billion market, mostly in the United States and Japan, with some delays in Onsen and some opportunities in South America.

	Technology area	Technologies under consideration	Market size and drivers
	Traditional hydro	Conventional hydro equipment and services	Canada's power will be more than 50% hydro through 2050. In 2020, there will be $420 billion in global capex for conventional hydro, mostly in large projects driven by governments.
	Unconventional hydro	Run of river, hydrokinetic turbines, marine power generation	Canada has natural expertise and some new technology. There is a large market opportunity if the technology is developed.
Trans-portation	**Advanced trains and aircraft**	Electric rail and urban transit, aircraft assembly, and engine design	Bombardier is the third largest aircraft original equipment manufacturer (OEM) ($10 billion in revenues in 2011) and also a major company in rail ($10 billion in revenues 2011). Canada attracts international suppliers and domestic growth.
	Fuel cell vehicles	Hydrogen fuel cells, charging infrastructure	Canada has significant investments in hydrogen fuel cell development. There is a large potential, but it is beyond 2020-2030.

These technologies enable the export or use of Canadian natural resources (e.g., enhanced hydrocarbon recovery, uranium mining, hydroelectric power), have received long-term technology investment (CCS, hydrogen vehicles), or are areas where Canada has a large global presence (e.g., advanced trains and aircraft). In Section B, we also evaluate the market size, growth, technology maturity, and drivers for these areas to compare them with the globally attractive areas.

Section B: Prioritized list of technologies attractive to Canada

ASSESSMENT OF TECHNOLOGY AREAS

Although all of the technologies on the list were chosen because of their global impact and value and/or their strategic importance to Canada, these criteria alone do not provide direct insight into the potential for Canada to compete in a particular area.

The assessment of whether Canada could successfully enter and compete in a market and the role government could play falls into two categories, shown in Exhibit 4. First is an assessment of the market's characteristics and attractiveness, including an evaluation of the size, growth, and market structure, the role of technology in the market along the value chain, and additional risks and challenges. Second is an assessment of Canada's competitiveness in the market, including any advantage that Canadian industry has today and any sustainable advantage Canadian industry could develop in the future.

EXHIBIT 4

Technology areas were assessed for global market attractiveness and the potential for Canada to compete

B1 Global market attractiveness

Market characteristics
- Size and projected growth
- Post-2020 growth potential
- Market stability/liquidity
- Number and size of players
- Regional vs. global markets
- Path to market for Canadian players

Technology role
- Technological maturity (e.g. R&D stage, pilot, commercialization, incremental cost-reduction)
- Competitiveness of different technologies
- Potential for disruptive technologies
- Cross-industry uses

Risks and challenges
- Commodity price exposure and substitution
- Socio-political trends and barriers
- Environmental goals
- Regional trade balances and labour

B2 Canadian competitiveness

Canadian advantage today
- Presence of large natural resources
- Large, globally competitive Canadian companies
- High-potential startup company activity
- World-class research and development
- Advanced regulatory structure and policy

Ability for Canada to create sustainable advantage
- Early, fluid market without clear technology winners
- Ability to use untapped large natural resource or geographical advantages
- Possibility of disruptive technologies that are not easily copied
- Ability to enact regulations in advance of other countries
- Ability to quickly reach large scale and low cost
- Ability to add high value through advanced engineering and integration

To assess Canadian competitiveness along the technology value chain and with the help of expert interviews, we first identified the components of the value chain that most impact the adoption of the technology and the growth of the market (Exhibit 5, Table 3). In many cases, we identified distinct areas where technological innovation was either overcoming or encountering barriers to growth.

EXHIBIT 5

We used several criteria to assess Canadian competitiveness across the technology value chain

Assessment	Example criteria
A **Highly competitive**	▪ Major Canadian natural resource (e.g., forest, oil sands) ▪ Strong, globally competitive company (e.g., Magna, Bombardier) ▪ Unique regulatory environment that gives Canada a business advantage (e.g., Crown-owned utilities or forest land)
B **Moderately competitive**	▪ Canadian companies on an equal footing with others in an established global market (e.g., Canadian Solar) ▪ Market is fragmented into regions with little cross-over (e.g., solar panel installation)
C **Potentially competitive**	▪ Canada has startup activity and investment comparable to other countries, and/or a lead in technology (e.g., small-scale CHP) ▪ Nascent market where winners have not yet been determined (e.g., hydrogen fuel cells)
D **Other countries have advantage**	▪ Other countries are leading an established market with little Canadian presence (e.g., LNG/GTL) ▪ Other countries have large R&D investments, incentives and commercial development compared to Canada (e.g., CBM)

Table 3 – In each technology area, the Canadian competitiveness of several individual technologies was assessed

	Technology area	Technologies under consideration	Canadian competitiveness
Fossil fuels	**Unconventional gas**	▪ Shale gas extraction	**A.** Large resource, Cdn drilling companies attracting investment
		▪ Supply chain and field management	**C.** Increasing scale driving Cdn environmental tech innovation
		▪ GTL and LNG technologies	**D.** Largest LNG/GTL are foreign multinationals (Shell, Sasol)
	Unconventional oil	▪ Bitumen extraction	**A.** Large resources with Cdn companies and leading technology
		▪ Upgrading and refining	**B.** US overcapacity reduces incentive for Cdn domestic investment
		▪ Environmental technology (water, land, air)	**A.** High water use during extraction driving environmental technology
		▪ Pipelines	**A.** Strong domestic Cdn expertise in pipeline construction/management

	Technology area	Technologies under consideration	Canadian competitiveness
Renewable and clean energy	**Solar PV**	▪ Wafer and ingot, module ▪ Balance of system (e.g., packaging) ▪ Integration (e.g., PV + components) ▪ Installation	**B.** Canada has one of the top 5 solar companies, most manufacturing in China **B.** Canada's top 5 solar company is an integrated BOS company **C.** New Cdn applications (e.g., PV/diesel/battery and smart grid) **B.** Installation markets large and regional, low barriers to entry
	Wind	▪ Wind turbine generator (WTG) ▪ Balance of systems and assembly ▪ Operation and services	**D.** Largest players in EU, China, and US, highly cost-driven **D.** OEMs sourcing globally; no large Cdn companies **B.** Wind farms are regionally operated, Cdn players advantaged in domestic market
	Bioenergy	▪ Biomass collection and processing ▪ Biopower ▪ Bioheat ▪ CHP	**A.** Large Cdn forests and dominant forestry industry **B.** Cdn pulp/paper industry has comparable biopower experience to EU/US **B.** Canada has experience in bioheat, but the EU is the market leader **C.** Emerging market with several small, growing Cdn startups
	Biofuels	▪ Biomass collection and processing ▪ Production of LC bioethanol ▪ Biorefinery products (green chemistry)	**A.** Large Cdn forests and dominant forestry industry **C.** Not yet cost-effective technology; Cdn feedstock driving commercialization with US regulations driving demand **C.** Nascent technology, several active Cdn startups
Distribution	**Smart grid**	▪ Metering ▪ Grid storage ▪ Other (demand/response management, software, integration)	**D.** Major players are foreign and market is consolidating **D.** US/China have major programs, some Cdn startup activity **B.** Some Cdn startup companies, but consolidation by foreign majors may buy them up or drive them out
Buildings and communities	**Energy- efficient buildings**	▪ Advanced windows ▪ HVAC ▪ Integration of EE technologies ▪ Pre-fabricated houses	**B.** One Cdn windows assembler in fragmented market **D.** Some small companies, but majors are foreign **B.** Installation and integration markets are mostly regional **B.** Some expertise and export, but increasing cost pressure
	Advanced lighting	▪ LED fabrication ▪ BOS (packaging, luminaire, control)	**D.** Largest players in Asia, highly cost-driven **D.** Some niche Cdn products, but increasing cost pressure
Energy-intensive industrial processes	**E-waste recycling**	▪ Collection and disassembly ▪ Precious metal extraction	**D.** High Cdn labour costs; lack of concentrated feedstock **B.** Some Cdn smelting presence, but existing majors are foreign

	Technology area	Technologies under consideration	Canadian competitiveness
	Waste to energy	▪ Equipment ▪ Engineering and operation	**B.** Some novel Cdn startups, but existing majors are foreign **D.** Limited Cdn adoption, given the lower tipping fees than the EU
	Water	▪ Water treatment equipment ▪ Operation and maintenance	**B.** History of Cdn technology innovation, but purchased by the US **B.** Mostly US and EU, but some major Cdn engineering firms
	Energy-efficient industrial processes	▪ Industrial process optimization	**B.** Market and technology leaders are in EU/Japan due to tight regulation; some Cdn expertise due to large industries
Trans-portation	**CNG/LNG fleets**	▪ NG engines ▪ Refueling infrastructure	**B.** One Cdn company with foreign partnerships **C.** Emerging NA market, large Cdn inexpensive NG resources
	Next-generation auto	▪ ICE engine technology ▪ Lightweighting ▪ Electric powertrain and engines	**B.** Cdn global supplier, but ICE engines foreign dominated **B.** Emerging market, with Cdn global supplier **C.** Emerging market, with Cdn global supplier; China has invested heavily in developing rare-earth resources
Fossil fuels	**Enhanced HC recovery**	▪ EOR ▪ CBM	**B.** Some Cdn EOR operations, but existing US majors **D.** Major investment in R&D and operations is in China
	CCS	▪ CO_2 capture ▪ CCS new or retrofit builds ▪ CO_2 transport and storage	**C.** Emerging market with major Cdn R&D and partnerships with foreign oil & gas majors for EOR **C.** Cdn expertise can be used if/when carbon price introduced **B.** Cdn natural formations and geological/MMV research, also pilot projects in US
	Gasification	▪ Gasification of coal to syngas or fuel	**D.** Existing market and technology leaders are foreign
Renewable energy sources	**Uranium mining**	▪ Uranium mining and processing ▪ Enrichment	**A.** Major Cdn resource and mining expertise **D.** Not pursued in Canada; US/EU have the major market share
	Nuclear technologies	▪ Traditional reactors (new, refurbishment, and decommission) ▪ Nuclear fusion ▪ Small-scale reactors	**B.** Cdn tech has ~10% of global market share, but slow growth and no new major projects **C.** Some promising Cdn R&D, but technology still immature **D.** No Cdn presence; the US is the world leader in technology
	Geothermal	▪ Power generation equipment ▪ Drilling and engineering ▪ CHP	**D.** Cdn adopts foreign technology **B.** Drilling is regional with some Cdn expertise due to mining **D.** Canada adopts foreign technology given cheap power and gas

	Technology area	Technologies under consideration	Canadian competitiveness
	Traditional hydro	▪ Construction and services ▪ Turbines and generators	**A.** Canada has major expertise in planning, engineering, construction **D.** Foreign EU majors have most of market share
	Unconventional hydro	▪ Run of river power ▪ Hydrokinetic power ▪ Tidal power	**B.** Small Cdn niche systems, but fragmented global market **C.** Promising Cdn pilots, but technology is immature **C.** Only plant in NA is Cdn, technology not yet economical
Trans-portation	**Advanced trains and aircraft**	▪ Electric and lightweight rolling stock ▪ Aircraft design and assembly ▪ Aircraft engine design	**A.** Cdn manufacturer has leading market share **A.** Cdn manufacturer has leading market share **B.** Cdn OEM and some foreign engine manufacturer presence
	Fuel cell vehicles	▪ Hydrogen fuel cells ▪ Refueling infrastructure	**C.** Market timing depends on fuel regulations; major Cdn R&D investment, emerging industry with foreign investment **C.** Refueling market is fragmented globally; no clear winning technology

In Exhibit 6, we show the "technology landscape" formed by considering both the market's attractiveness and Canada's ability to compete. The vertical axis represents the overall attractiveness of the market. At the top are large, fast-growing markets with opportunities and paths to market for many companies, including Canadian companies. At the bottom are markets that are either small, poorly defined, highly fragmented, and regional (without the possibility of consolidation) or very early in technology maturity – markets where it is unclear how any global company, including Canadian companies, can capture significant value. In the middle are markets that straddle the two – those with clear prospects for growth but uncertainty about the time frame or where and which technology will become dominant.

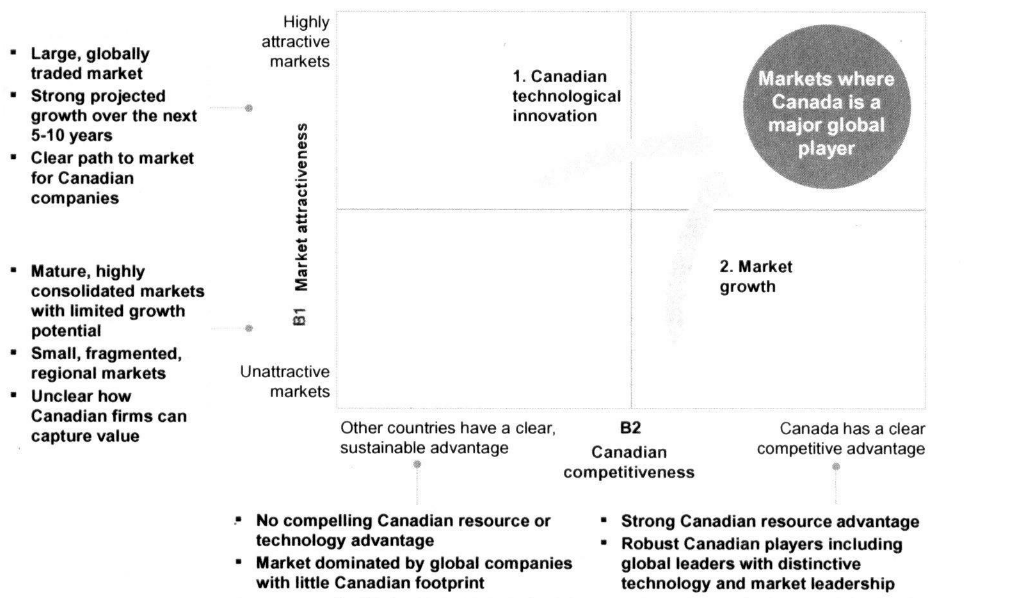
The horizontal axis measures Canada's current advantage. The rightmost region contains markets where Canada has a clear sustainable advantage, usually because of a resource advantage, such as large uranium deposits. In the middle are markets where Canada has just as much advantage as any other country (either because it has a world-class company or because the market is still in

flux). On the left are markets where other countries have strong existing advantages in either resources or established companies.

In this framework (Exhibit 6), the large attractive markets where Canada is a well-established technology power are in the upper right – in these markets, Canada will need to maintain its advantage. The potential to develop new opportunities for Canada lies in the sectors surrounding the upper right. As Arrow 1 indicates, Canada can develop potential by creating a sustainable Canadian advantage through research and development, early commercialization, and scale and become a major technology power in an already large market. As Arrow 2 indicates, Canada can also unlock value by maintaining an inherent advantage and encourage the global growth of a new market.

EXHIBIT 6

The most promising areas for technology investment will be where innovation can greatly increase Canada's ability to compete over time



When market attractiveness, Canadian advantage, and Canadian potential for competitiveness were taken into account, the technology areas fell into five distinct categories, as shown in Exhibits 7 and 8.

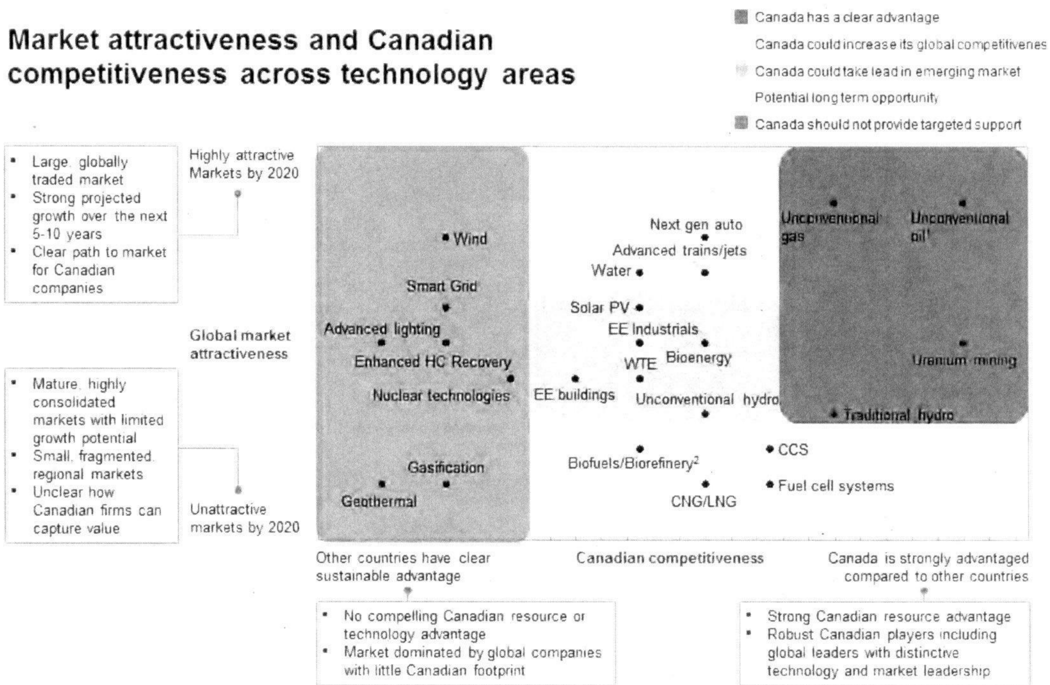
EXHIBIT 7

Technologies fell into five natural categories when market attractiveness, Canadian advantage, and potential were taken into account

Group	Market attractiveness	Canadian advantage	Investment thesis	Technology areas
Canada has a clear advantage	▪ Large global market for product today ▪ Expected to grow through 2020	▪ Strong natural resource that produces exportable commodity ▪ Canadian industry leadership in niche areas	▪ Develop technologies to reduce cost of extracting exportable commodity ▪ Secondary potential to export tech/services	▪ Unconventional oil[1] ▪ Unconventional gas[2] ▪ Uranium mining and enrichment ▪ Traditional hydro
Canada could increase its global competitiveness	▪ Large global market by 2020	▪ Existing globally competitive Canadian anchor company in key part of the value chain	▪ Export technology, equipment, services (e.g., electric motors, water services)	▪ Next-gen automobiles ▪ Advanced aircraft ▪ Water
Canada could take the lead in an emerging market	▪ Large global market by 2020 ▪ Emerging technologies could be disruptive	▪ Some Canadian industry presence and some technology development	▪ Export technology, equipment and services once developed (e.g., NG engines, integration services)	▪ Energy-efficient buildings ▪ Energy-efficient processes ▪ Bioenergy[3] ▪ Unconventional hydro ▪ Solar PV offgrid ▪ Waste to energy
Potential long-term opportunity	▪ Global market potential post 2020 ▪ Emerging technologies still immature today	▪ No established global players ▪ Some Canadian technology development	▪ Export technology, equipment and services once developed (e.g., CCS testing, tidal power generation units)	▪ 2nd gen biofuels/biorefinery ▪ CNG/LNG trucks ▪ CCS ▪ Fuel cell vehicles
Other countries have a clear advantage	▪ Technology is mature and/or commoditized	▪ Market and technology leaders are outside Canada	▪ Mostly domestic services for imported technologies (e.g. installations and maintenance)	▪ Nuclear technologies ▪ Enhanced HC recovery ▪ Gasification ▪ Wind ▪ Geothermal ▪ Smart grid[4] ▪ Advanced lighting

1 Includes transportation infrastructure, e.g., pipelines
2 Includes gas to liquid (GTL) and liquid natural gas (LNG)
3 Canada does not have a clear market or technology leadership in bioenergy
4 Includes demand management, demand response, and T&D power electronics

EXHIBIT 8



1 Global capex and sales from Canadian oil or gas only
2 Global capex and sales from cellulosic biofuels only (includes agriculture waste)

SOURCE: McKinsey Global Energy Perspective Model, market research, expert interviews

In the first category, the upper-right corner of the framework, are markets in which Canada has a clear advantage in a large, growing global market. Included in this category are unconventional oil and gas, uranium mining, traditional hydroelectric, and biomass technologies. In most of these cases, the advantage is due to an existing natural resource (e.g., large unconventional oil reserves, uranium deposits, domestic hydroelectric power, or forests) and an established, world-class Canadian industry. In these areas, many of the opportunities lie in continuing to develop technologies to maintain this market position.

In the second category, the upper middle of the framework, are large and growing markets where Canada is competitive globally but is not a dominant technology power. This category includes next-generation automobiles, advanced aircraft, water technologies, and nuclear technologies; in all of these areas, Canada has major global companies (e.g., Magna, Bombardier) in the value chain, but it is not the top technology nation. In this category, the opportunity would lie in expanding the existing advantage, either by innovating new technologies more rapidly than competitors or by exploiting an inherent resource advantage.

In the third category, the middle of the framework, are moderately sized emerging markets expected to grow strongly but in which the technology path is not entirely clear. Included here are energy-efficient buildings, energy-efficient processes, off-grid applications of solar PV, waste-to-energy technologies, and biofuels. There are some Canadian companies and technologies in these areas but, because of the technology's immaturity, it is unclear whether they are significantly more competitive than technologies being developed elsewhere. In these areas, Canada has an opportunity to take the lead in an emerging market by becoming a technology leader and growing the global market.

The fourth category lies in the lower middle and right of the framework. These are nascent technologies where Canada may have a neutral to strong advantage, but the market is highly uncertain. Included here are technology areas such as CCS, CNG/LNG trucks, unconventional hydroelectric, and hydrogen vehicles – all areas where Canadian startups are doing significant work but for which market adoption is likely to be post-2030. In these areas, the opportunity for Canada is to continue to research and develop the most promising areas and seek short-term applications where possible.

The last category occupies the entire far-left side of the framework. These are areas where the technology is mature or commoditized and where other countries have large advantages, either because of natural resources and/or large existing globally dominant companies. This category includes enhanced hydrocarbon recovery (the United States and Russia), gasification (China), wind (China, the United States, and the European Union), geothermal (Japan and the United States), smart grid (the European Union, China, the United States, and other global companies for most of the value chain), advanced lighting (China and Taiwan), and e-waste (China and the European Union). Although it may be possible for Canada to become a major energy power in these areas, a greater opportunity would be in adopting the technology domestically to reduce Canada's costs and concentrating on high-value-added technology applications.

This categorization does not tell us how the government should act – i.e., the technologies in the upper-right corner would not necessarily receive additional aid from the government, and nor would those on the left or in the middle be ignored.

On the contrary, many of the industries in the upper-right corner already have attractive incentives to continue funding research and development, and to invest much larger sums than are available through government. In these cases,

government involvement may be limited to tailoring regulations to ensure that development continues in a direction conducive to long-term Canadian industry stability, growth, and strategic concerns (e.g., environmental). Similarly, in the far-left category, relatively few incentives exist for Canadian industries and, in some cases, the best role for government may be to encourage the adoption of technologies for domestic use and cost savings. In the middle categories, the government could play multiple roles to enable industries to overcome barriers to technology development and become globally competitive by providing subsidies, clear regulatory frameworks, and other incentives. We examine these possibilities in Section C. The immediately following sections detail our analysis for the technology areas and justify their positions on the matrix in Exhibit 9.

FOSSIL FUELS: UNCONVENTIONAL OIL

Technology areas under consideration

The unconventional oil technology areas considered in this report fall into three categories: 1) those required to extract bitumen product from the oil sands, including drilling, mining, Steam-Assisted Gravity Drainage (SAGD), and other in situ techniques; 2) those for converting bitumen into an exportable product, including upgrading and refining; and 3) those to make the process cost-effective and environmentally acceptable, including water and air treatment, greenhouse gas and volatile organic compound reduction, land remediation, and tailings management.

Also considered here is pipeline construction for the export of oil and gas from Canadian fields, primarily to the West Coast for shipping to Pacific Rim destinations. Several oil pipelines have been proposed, including the Enbridge Northern Gateway, the Kinder Morgan Trans Mountain Pipeline, and the Keystone XL. Proposed gas pipelines include the Mackenzie and Alaska pipelines.

This area also contains technologies necessary for pipeline construction and preventing pipeline leaks, including automated pipeline corrosion and leak monitoring.

Market overview

The market for Canadian unconventional oil products is large and fast growing, driven by worldwide demand for oil and advances in extraction technology. Crude oil prices are expected to remain above the breakeven point for current extraction technologies ($60 to $70 per bbl), the total projected volume of oil derived from sands is expected to reach 3 million to 4 million bbl per day by 2020, and revenues are expected to reach $100 billion to $300 billion worldwide. Part of this revenue will be derived from the 20 percent of oil that is extracted using mining technologies, but the bulk will be derived from the 80 percent of reserves that are extracted using in situ techniques.

Canada has several options for reaching markets for its unconventional oil, but it faces varying economic, policy, and technological hurdles.

- **Export to US refineries.** Canadian exports to the US refinery market face a discount because of pipeline transport costs and high supply – and this discount will grow as the volume increases. Several increases to pipeline capacity have been proposed, including reversing some current Canadian-US pipelines and building the Keystone XL pipeline extension to locations in Illinois, Oklahoma, and the Gulf Coast. The Keystone XL pipeline in particular has met with strong political and social resistance.
- **Export to international markets.** Exports to markets in Asia are limited by the capacity of the Western pipelines to the West Coast, which are currently oversubscribed by 69 percent. Proposed pipelines to the West Coast have met with resistance from the British Columbia government, aboriginal groups, and environmental advocates. Proposals include:

    A side-by-side addition to the Trans Mountain pipeline. The current pipeline carries 300,000 bbl per day to the Greater Vancouver area and is at capacity, with a 69 percent over-nomination rate. The proposed addition to the existing route would more than double total capacity to 750,000 bbl per day.

    The Enbridge Northern Gateway route to Kitimat, British Columbia, which would provide total capacity of 525,000 bbl per day crude outgoing capacity and 193,000 bbl per day incoming natural gas condensate.

Despite automated monitoring of pipeline corrosion and automated pipeline inspection, major spills still occur and are highly publicized, causing significant social unease regarding pipelines.

- **Domestic use or export to the Canadian East Coast.** The Canadian East Coast refineries are currently configured for the lighter North Sea Brent oil, and they would have to be retrofitted to handle the heavier products from unconventional sources.
- **Upgrading and exporting refined products.** Currently, bitumen is mixed with natural gas condensate to reduce its viscosity for transport through pipelines, but it may be economic to further upgrade the bitumen into a higher-value product before transport, reducing the volume that must be transported and potentially avoiding the North American discount. This would require large investments in oil refining capacity.

Technology overview

Unconventional oil extraction technologies are crucial for the success of Canada's unconventional oil industry, as they enable oil to be extracted at costs competitive with crude derived from conventional sources. Continuing decreases in costs and increases in efficiency along all parts of the value chain will be required as the easily accessible parts of oil reserves are depleted and the less accessible reserves are exploited.

All parts of the oil sands value chain are actively developing technology. In drilling and extraction, all companies are improving extraction performance by experimenting with electrothermal and radio-frequency heating techniques, in situ steam, and different types of solvents for extraction. An essential step in the development of these technologies is operation in the field at scale, which will decrease productivity temporarily. Additionally, although SAGD was developed in collaboration with the Canadian federal and provincial governments and several oil industry majors (in which an existing, non-productive field was used to pilot the SAGD technology), many companies view other extraction technologies as central to their competitive advantage and are unwilling to collaborate on development or demonstration.

Collaboration in technology development is more widespread in the wastewater recovery, recycling, tailings treatment, and land remediation parts of the oil sands value chain. These are seen as areas where a competitive advantage is not as important and where collaboration can help all companies. COSIA (Canadian Oil

Sands Innovation Alliance) is a consortium focused on improving water and tailings management, greenhouse gas emissions, and land remediation.

Canadian advantage

Canada's advantage in oil sands is derived from its ability to control access to the oil sands, its success attracting foreign investment, and the growth of large domestic companies well-positioned to exploit value from the oil sands.

Canadian companies are present along the entire value chain, including large global firms such as Suncor, Canadian National, Canadian Oil Sands/Syncrude, and Cenovus, all of which possess major fields and technologies. Multinational oil majors operating in Canada include ExxonMobil and Shell, and there is some M&A activity from large foreign interests, including a proposed acquisition of Nexen by CNOOC.

Several leading technologies developed in Canada are now used by Canadian and multinational companies, including SAGD and COSIA. For example, as oil sands extraction entails managing large volumes of wastewater, Canadian companies such as Suncor and Cenovus have adapted techniques from the mining industry and are developing new techniques that may be applicable beyond the oil sands. Because global standards will require increased water conservation and strict wastewater regulation across all industry sectors, such innovations may prove especially advantageous.

Canada has expertise building pipelines in its northern regions, developing a large and growing oil-export industry, and negotiating regional environmental objections. Canada's expertise in pipeline monitoring during operation includes:

- Intrusive robots to monitor pipe-wall thickness (e.g. InvoDane)
- External monitors that detect changes in the pipeline's condition (e.g., TISEC)
- Expertise in strain-based design requirements imposed by frost heave and thaw settlement.

Strong opposition from local populations are consistent themes in building new pipelines (e.g., the Northern Gateway pipeline was proposed first in the mid-2000s and has been postponed several times since). Issues include the environmental threat to native wild salmon habitats and providing adequate

Investment thesis

Canada's domestic drilling and extraction industry is a large source of employment and national productivity; for example, 15,000 people are directly employed in Alberta by multinational oil producers, oil-field services companies, and small regional drilling operators. To maintain Canada's advantage in oil sands production, Canada could continue to lower the cost of extraction through innovation in drilling, extraction, and wastewater management technologies, lower the barriers to oil export (discussed in more depth in the pipelines section), and actively seek new applications for technologies related to the oil sands, like wastewater management.

In drilling and extraction, the oil industry is already making large capital investments of $18 billion to $20 billion per year that are forecasted to continue through 2015-2020. As mentioned, since much R&D is conducted by individual companies, the need to make tradeoffs between maximizing output and running full-scale pilots is ever present. For long-term competitiveness and protection against oil-price volatility, technological advances must continue to push the cost of extraction down to at least be competitive with emerging sources. Whether the industry offers sufficient incentives for long-term research and development, or if additional government actions might be considered, is discussed in Section C.

Pipelines are one possible way of maintaining Canada's competitiveness in international oil and gas markets. The volume of oil from Western Canada is expected to triple from 1.6 million to 5.0 million bbl per day between 2010 and 2030. Currently, due to excess supply, the bulk of Canadian oil and gas is processed at US refineries in the Midwest at a discount. To remove the discount, it will be necessary to build pipelines that reach US West Coast international crude and natural gas markets directly.

Action on several pipeline proposals will increase Canada's access to North American refineries. For example, the Keystone XL pipeline will increase the flow of oil to Texas refineries, and new west-to-east pipelines connecting Western sources to Canadian refineries.

FOSSIL FUELS: UNCONVENTIONAL GAS

Technology areas under consideration

Methods for extracting natural gas from Canada's unconventional gas fields is another technology area. Value chain elements we examined included drilling, fracturing, completion, and water management of the gas wells. We also considered supply chain management, field management, field exploration and evaluation, and gas hydrate extraction.

Other related technologies we analyzed were transportation and conversion techniques for natural gas, including natural gas pipelines, gas-to-liquid (GTL) processes for converting natural gas to liquid hydrocarbons (e.g. diesel) by the Fischer-Tropsch process, and liquefied natural gas (LNG) transportation technologies.

Market and technology overview

The global natural gas market is large and fast growing, driven by technologies that enable low-cost extraction of gas from large gas fields discovered in North America.

Total Canadian unconventional gas production is expected to reach 30 percent of North American and 50 percent of US gas production by 2020. Even so, Canada faces a discount when selling its product because our transportation costs to the United States are too high. This disadvantage will be mitigated when proposed pipelines are built to transport gas from the Beaufort Sea in the Northwest Territories to Alberta, or to coastal LNG export facilities, or to Asian markets, as will the proposed Alaskan gas pipeline to connect reserves on the Alaska North Slope to Calgary. However, like most proposed oil pipelines, they have all met regional resistance and have become less attractive economically. with the recent shale boom in the continental USA.

The expenditure on gas extraction services is large. By 2020, field service spending in North America will exceed $38 billion for unconventional gas, $7 billion for tight gas reserves, and $18 billion for drilling services. Smaller services markets (less than $1 billion) are predicted for coal bed methane and methane hydrate extraction.

Decreases in the cost of natural gas are driven by incremental improvements in drilling technology and knowledge of gas fields. Techniques tend to be

practical, easily copied, and specialized to particular geologies. As fields expand in size and number of wells, supply chain management, field management, field exploration and evaluation, and field instrument networking and automation are continuously innovating.

A controversial part of gas extraction is the practice of hydraulic fracturing or "fracking," in which large volumes of water and other liquids are injected into shale basins at high pressure, creating fractures through which gas can escape. Concerns include contamination of groundwater and seismic activity. The practice has been banned in Quebec, Nova Scotia, and France. As water pollution regulations grow increasingly strict around the world, technologies developed to treat, reuse, and recycle the large amounts of water used in fracking, and technologies for alternative fracking fluids, may find application in other sectors, such as mining.

The GTL and LNG markets are driven by the increasing price differential between oil and natural gas. The technology is mature and proven at scale, with GTL profitable above $70 per bbl of oil. Most GTL commercial scale plants are large, including Shell (140,000 barrels per day, $24 billion capex) and Sasol plants (29,000 barrels per day) in Qatar. Recent innovations by Rentech, Syntroleum, and CompactGTL include small-scale, mobile GTL plants for use in small gas fields.

The Fischer-Tropsch process is energy-intensive, using 40 percent of the gas energy for conversion. However, the product is 71 percent low-sulfur diesel, which has a high global demand forecast due to low-sulfur regulatory requirements.

Canadian advantage

Canada has extensive unconventional gas resources and some horizontal well drilling expertise, including the Montney, Horn River, and Duvernay shale fields.

The drilling market covers most of North America and Canada's numerous but small drilling companies must compete with a handful of large North American oil companies. For example, Texas-based National Oilwell Varco has 50 to 60 percent of the drilling equipment market share, and owns several US and Canadian oil-field services and equipment (OFSE) companies, including Haliburton, Baker, Schlumberger, Weatherford, and the Canadian company

Calfrac that together have 40 percent of the pumping and fracturing market share and an 80 percent share in well completion.

Drilling, pumps, pipes, and fracking comprise 50 to 60 percent of the cost of drilling. In some cases, smaller regional companies are often better adapted to local geology and employ more cutting-edge techniques than the large OFSEs that are unwilling to cannibalize their existing technologies. For example, XACT Inc. a Calgary-based company, is developing advanced acoustic drilling telemetry technologies and GASFRAC, another Calgary-based company, is developing a gelled LPG alternative to conventional fracking fluids that reduces water pollution. In these cases, multinational oil companies have been willing to develop smaller OFSEs (fewer than 50 rigs) into larger operators with better efficiency and reliability. Some potential exists for these companies to expand into other areas like China, but expertise is often highly dependent on geology, limiting this opportunity.

Canada is also attracting potential GTL investments because of its vast resources and comparative stability. For example, Sasol has signed an option to build on an industrial property in Edmonton (96,000 barrels per day, $10 billion in exports).

Investment thesis

To continue to be competitive in natural gas, Canada could seek opportunities to export unconventional gas through GTL and pipelines, stimulate the domestic natural gas market, and potentially export services such as hydraulic fracking and gas field management. Regional Canadian companies may have first-mover advantages, particularly if water and other regulations are systematically tightened in Canada before being adopted elsewhere.

GTL and LNG are potential routes to market for Canadian unconventional gas. Natural gas in North America is currently oversupplied, depressing prices for the long term and making export to Asia attractive. GTL is more expensive than LNG and has a higher GHG footprint, but the diesel it produces can be used in domestic markets or exported to international markets. In the US market, demand for low-sulfur diesel has been increasing due to EPA mandates for less than 15 ppm by 2010 for diesel used in trucks, cars, locomotives by 2015, and other vehicles.

FOSSIL FUELS: ENHANCED HYDROCARBON RECOVERY

Technology areas under consideration

The enhanced hydrocarbon recovery technologies considered in this report fall into three categories: 1) enhanced oil recovery (EOR) using thermal, CO_2, or hydrocarbon injection; 2) coal bed methane (CBM) recovery using CO_2 injection; and 3) the extraction of gas hydrates.

Market and technology overview

Enhanced hydrocarbon recovery is a large and growing market driven by the depletion of large oil fields and increasing oil and gas prices. Mostly mature technology is used for EOR, but there is room for technological innovation in CBM and gas hydrates. Currently, there is a $126 billion global market for EOR, and moderate growth driven by US efforts to improve domestic oil production. There is also a $9 billion market for CBM, with growth driven by China because it lacks conventional gas resources. The economic attractiveness of both EOR and CBM depend on oil and gas spot prices; CBM is less economical in North America because of the low gas prices caused by the recent unconventional gas boom.

Canadian advantage

Canada has large natural oil and coal resources, but the United States, China, and Russia are today's technology and market leaders. Enhanced hydrocarbon recovery technology that uses CO_2 injection is often paired with carbon capture technology. Projects like Weyburn-Midale in Saskatchewan, currently use CCS technology for EOR. Canada has no specific advantage in CBM technology except that foreign companies have recently expressed interest in Canada's few operating CBM facilities (e.g., Toyota has invested in Encana's CBM technology). Methane hydrates in Canada's north are not likely to be economical in the 2020 time frame, since shale gas extraction is likely to continue growing.

Investment thesis

Canada can best derive value by continuing to be an adopter of EOR technology for domestic oil reserves. In the longer term, economical CBM extraction

requires better technological innovation and probably partnerships with other countries that have high CBM reserves (e.g., China).

FOSSIL FUELS: CARBON CAPTURE AND STORAGE

Technology areas under consideration

The carbon capture and storage (CCS) technologies considered in this report fall into three categories: 1) pre-combustion, post-combustion, and oxy-fuel capture technologies; 2) the transport and storage of carbon dioxide; and 3) the building of new CCS power plants and the retrofitting of existing ones.

Market and technology overview

The current CCS market is small and focused on R&D and pilot demonstration projects. Although some regions have implemented carbon prices (e.g., Alberta) and GHG regulations, the high carbon prices and the decreased cost of CCS necessary for large-scale adoption are not expected to occur before 2015. In the shorter term, target applications for CCS appear to be enhanced hydrocarbon recovery, natural gas processing, and oil sands upgrading. If carbon prices increase sufficiently, CCS may also be used in retrofits of existing coal and natural gas power stations, as well as new builds. These applications are contingent upon developing measurement, monitoring, and verification (MMV) techniques to confirm secure sequestration, an attractive carbon price, well-developed regulatory and carbon accounting rules, and a functioning carbon market.

In 2020, the GEP model predicts a modest $4.2 billion global capital expenditure on CCS, mostly for new builds of natural gas CCS power plants. In 2030, spending is predicted to grow dramatically (based on a $50/tonne carbon price – please see the GEP model predictions in Appendix: GEP Model Results), with $260 billion spent globally on new gas CCS systems, new coal CCS systems, and retrofitted power plants of any fuel source. As discussed in the Appendix, quadrupling the carbon price to $160 doubled the predicted CCS spend in the United States and Asia in 2030, while increasing the rate of technology cost-reduction for competing RES (i.e., wind and solar) decreased CCS adoption by half.

The technology areas associated with CCS are still in the R&D and pilot phase. Oxyfuel, pre-combustion, post-combustion, and chemical looping combustion have been demonstrated in the laboratory, but major barriers remain in engineering the large-scale, efficient processes needed to absorb large amounts of CO_2 produced during coal and natural gas power generation.

Depleted geological saline aquifers or depleted natural gas reservoirs are the current candidates for long-term, large-scale CO_2 sequestration. The scale and uncertainty associated with this technique has drawn public attention, and made extensive characterization, measuring, monitoring, and verification (MMV) mandatory requirements for approval. This is especially relevant in Canada, since sequestration will likely be built on Crown land where the government assumes the risk of long-term leakage. With much of the regulatory framework yet to be determined, including long-term liabilities and carbon accounting rules, there is much uncertainty about the long-term economic viability of CCS sequestration. Other risks include possible negative public perception of CO_2 storage due to the risks of leakage and groundwater contamination, technological risks, and the possible phase-out of coal in countries that are likely to lead in adopting carbon prices.

Canadian advantage

Canada has made large investments in CCS technology development and pilots, establishing itself as a global leader in technology and adoption. The Canadian federal government announced $240 million in funding in 2008 and $850 million in 2009, along with a number of smaller announcements. Alberta announced $2 billion in funding in 2008.

Canada has an advantage in the experience it has gained operating pilot and commercial-scale plants, including large-scale projects such as the Weyburn-Midale carbon dioxide projects, the final phase of which operated between 2005 and 2011. Another area where Canada is advancing rapidly is in large- and small-scale CO_2 sequestration.

There are several pilot and commercial-scale projects, such as:

- The Weyburn-Midale project in Saskatchewan that transported CO_2 captured from a gasification plant in North Dakota to EOR reservoirs in Saskatchewan from 2005-2011.

- The Quest project near Edmonton, Alberta, which will lower upgrader emissions by as much as 35 percent, begins operation in 2015
- The SaskPower and Hitachi partnership that will demonstrate new capture technologies beginning in 2014
- SaskPower Boundary Dam project, a $1.24 billion government-industry partnership using CanSolve carbon capture technology to retrofit a coal-fired plant with CCS for EOR
- The Husky pilot EOR plant that will be potentially operational in 2014
- The Aquistore CO_2 storage site characterization and inspection demonstration project
- The Alberta Carbon Trunk Line that will transport CO_2 from Alberta and may be operational in 2014
- The Swan Hills in situ coal gasification project that will be integrated with CCS and possibly operational by 2015.

Examples of startup activity in Canada include:

- Inventys – CO_2 capture at $15/tonne; based in British Columbia
- CO_2 Solutions – novel enzymatic process; based in Québec
- CarbonCure – CO_2 sequestration in cement; based in Nova Scotia.

Investment thesis

In the long run, Canada, with its large coal, gas, and oil reserves, benefits from the development and deployment of economical, large-scale CCS technologies. Developing large-scale carbon sequestration from fossil fuel power generation is a major, although not the only, long-term objective of CCS research. Because large-scale adoption of CCS depends heavily on both regulation and the price of alternatives such as wind, solar, and natural gas, it is difficult to predict when and how extensive CCS adoption will be. With predicted low prices of natural gas in North America and assuming that significant carbon regulation is developed only by OECD countries, CCS expenditures in power generation are not expected to grow strongly until after 2030.

To mitigate these risks, in the near term Canada could continue to seek immediate applications for CCS, such as in enhanced hydrocarbon recovery and industrial processes. In many cases the value added by CCS technology to an existing

industrial process, or to recover oil from an existing reservoir, can be more than sufficient to justify its cost, even if the technology is still too costly for pure CO_2 abatement. Its experience creating sustainable business models and robust and efficient technologies, beginning at these smaller scales, will be crucial to Canada's competitiveness when the time eventually comes for large-scale global adoption of CCS.

FOSSIL FUELS: GASIFICATION

Technology areas under consideration

Considered here are gasification processes that convert coal to liquid fuel (CTL). Not considered are similar technologies to turn biomass or municipal waste into liquid fuels.

Market and technology overview

The gasification market is small and growing moderately, with mostly regional applications in China and South Africa. The global CTL market is currently $4 billion and is projected to grow rapidly until 2015, driven by chemical and power industries in China, followed by a period of slower or flat growth. In most cases, CTL is not economically viable without subsidies or high oil prices. The technology is based on the Fischer-Tropsch process and is relatively mature.

Canadian advantage

Although Canada has large coal deposits, there is limited economic value in using gasification technologies to convert these to oil, especially since Canada has plentiful, low-cost oil resources. China, however, faces long-term difficulty importing sufficient liquid fuels to meet its needs and is exploring gasification technologies for its large coal deposits. It is looking at both importing technologies and developing its own domestic industry.

It may be possible, however, to adopt existing CTL technologies to low-value biomass, taking advantage of what would otherwise be a large, wasted resource.

Several non-Canadian companies, including Shell, Sasol, and GE, are market leaders in gasification technologies.

Investment thesis

Canada may be able to adapt existing CTL technologies to low-value biomass to create a higher-value fuel from waste material. Although it may be possible to export CTL technology to China, Canada is not a global leader and is under no long-term pressure to develop new CTL technologies.

RENEWABLES AND CLEAN ENERGY: SOLAR PV

Technology areas under consideration

Considered in this report are all the steps along the solar module value chain, including module manufacturing (poly-Si crystal production, ingot and wafer manufacturing, and cell and photovoltaic module assembly), the balance of systems (inverter, mounting, cables, and installation), and integration and support (engineering, procurement and construction, concentrated photovoltaic (CPV) systems, off-grid applications, and power production ownership).

Market and technology overview

The solar PV panel market is large and fast growing, and it is expected to reach $325 billion capex by 2020 and $962 billion by 2030. It is driven by increasing power demand and decreasing solar PV production costs (40 percent decrease by 2015, 60 percent decrease by 2030). The largest expenditures are projected to be in Asia ($440 billion by 2030) to meet power needs.

Most of the solar PV value chain is commoditized, with large manufacturers based in China. Some niche opportunities exist downstream in the value chain (e.g., the integration of solar PV modules into other products and installation), but most innovation occurs through incremental improvements in efficiency and economies of scale. Large investments in China have resulted in an oversupply that is driving downstream consolidation. There is also a trend toward downstream specialization to serve customer needs.

With installations totaling 40MW in 2011, the concentrated photovoltaic (CPV) market is small, and most technology is at the pilot stage. As in the main solar industry, many companies are insolvent or being acquired. In the long term, CPV technologies face competition from low-cost, thin-film photovoltaic panels. Thus main applications will be larger installations in areas that receive abundant direct

sunlight where CPV can offer a cost advantage because of its lower photovoltaic content.

Canadian advantage

Canada has one large-scale, integrated, solar PV module producer that is an established low-cost company, and several smaller, struggling companies.

Canadian Solar reported $1.9 billion in revenue and 1,323MW shipped in 2011. The company is based in Ontario, but most of its operations (80 to 85 percent) are in China. Although one of the lower-cost producers in the industry, it is under cost pressure like the rest of the industry.

Canada has several smaller companies with significant VC backing, but they are struggling. More than $150 million in VC capital has been invested into a mix of companies along the value chain. Many of these are being acquired or facing significant operating problems. One notable company is Morgan Solar CPV, which completed a 28.8 Series B investment in 2011 and which counts Enbridge among its investors. It will begin production in California.

Given its low hydroelectric power cost, Canada has little domestic need for solar except in niche, off-grid areas. Although solar is more expensive than natural gas even during peak hours, it has a political advantage. Namely, new solar installations do not face the community resistance that new natural gas plants encounter because of their GHG emissions. One promising niche is in off-grid and rural power generation, where solar can be combined with other technologies (battery storage, diesel) for rugged, reliable, and efficient modular power.

Investment thesis

Canada's opportunity is to focus on niches like off-grid power generation for domestic and possible export use. Off-grid areas (e.g., rural areas with high distribution costs) may benefit from reliable, efficient local power generation, and technologies may be exportable to the large off-grid market expected to expand in developing countries.

A second opportunity is downstream solar system integration into smart grids. Smaller solar companies may be able to serve regional utilities and companies in domestic smart grid applications and, with sufficient expertise, could enter the US market.

A third opportunity is a niche play in concentrated solar PV. The challenges of solar PV lie in systems integration and installation; expertise is these areas is being developed in Canada. It is unclear, however, if this advantage will be sustainable over the long term.

RENEWABLES AND CLEAN ENERGY: WIND

Technology areas under consideration

Considered here is the wind turbine supply chain (tower, blade, generator, power electronics, etc.), OEMs, and wind turbine farm operators. Also considered are the technologies necessary for advanced drivetrains and control (e.g., permanent magnet generators, advanced gearboxes, rotors, wind-speed forecasting and optimization).

Market and technology overview

The global market for wind is large but mostly cost-driven, with major global companies outside Canada incrementally reducing costs through improved manufacturing processes and design. The wind global market is forecasted to grow to $680 billion by 2020, with the largest growth in the United States, the European Union, and China.

The entry of Chinese manufacturers has led to widespread cost pressure along much of the value chain, and increasing standardization of components is leading to commoditization. As in the automobile industry, OEMs are optimizing supply chains and are able to place cost pressure on suppliers.

OEMs of wind turbines are searching for differentiating features, which is driving innovation. Drivetrain reliability has increased with the introduction of new gearbox and generator technologies, and efficiency is improving through wind forecasting, dynamic load modulation, and advanced rotor design. These niches offer some opportunities for advanced technology companies.

Canadian advantage

Although Canada has large areas suited to wind farms, and wind is a potentially cost-effective energy source for remote locations where long-distance power

distribution is expensive, in most urban areas wind is not strongly cost-competitive with baseline nuclear/hydropower.

Canadian manufacturers build towers and blades and provide engineering services, but they face stiff competition from China. Although Canada is geographically close to the United States, this advantage is fading with the introduction of low-cost offshore production. Canada also builds specialized components (e.g., cold-weather blades), but these are relatively small niches with competition from Denmark and other cold climate EU countries.

Investment thesis

Canada's opportunity is limited to niche domestic consumption, particularly off-grid power generation. Continuing interest in wind is driven, however, by its low capital cost compared to new hydro and nuclear builds, its low GHG profile compared to natural gas-derived power, and low regulatory barriers compared to hydroelectric power. These characteristics have stimulated the installation of wind farms through programs such as Ontario's feed-in tariff (FIT).

A second opportunity is in high-technology component supply, where smaller suppliers could develop advanced components and operational technologies (e.g., wind forecasting, load modulation). It is unclear, however, if there is a sustainable Canadian advantage here, as many countries have advanced wind engineering technology.

RENEWABLES AND CLEAN ENERGY: GEOTHERMAL

Technology areas under consideration

The geothermal energy technologies considered in this report fall into two categories: 1) power generation using geothermal resources; and 2) combined heat and power (CHP) applications. One technology area not under consideration is shallow or ground-level heat extraction by heat pumps.

Market and technology overview

Geothermal is a small, slow-growing market with mature technology and with drilling and piping dominating the cost of installation and distribution. The market today is $3 billion, mostly in regions where geothermal resources are

available – mostly in the United States, Iceland, and Japan. Geothermal locations in Canada are often close to low-cost hydroelectricity sources or far away from urban locations, so there is little incentive to develop them. Technologies for both power generation and CHP have similar heat exchangers, pumps, and turbines as thermal electricity generation. The leaders in geothermal technologies are well established and, except for small installations, leave little room for competition in both innovation and implementation.

Canadian advantage

Although Canada has a large total geothermal potential (CanGEA estimates 5000MW of accessible geothermal in Western Canada alone), most sites are not economic either because of their remoteness or because of competition from cheaper hydroelectricity. Canada has extensive infrastructure and services for drilling, but these are generally difficult to export.

Canada has several small companies active in drilling, technology installation, and R&D. Ram Power Geothermal has operations in British Columbia, Nevada, California, and Nicaragua. Alterra Power Corp. has geothermal operations in Iceland and Nevada and additional renewables operations in Vancouver and British Columbia. Borealis GeoPower is a private geothermal company developing greenfield and brownfield geothermal projects in Canada.

Investment thesis

Canada's opportunities in geothermal are likely limited to value creation through small-scale domestic power generation and some CHP applications that are attractive economically or as a renewable energy commitment.

RENEWABLES AND CLEAN ENERGY: URANIUM MINING

Technology areas under consideration

The areas considered here include uranium mining, conversion, reprocessing, fuel fabrication and reclamation, mining waste management, and waste fuel disposal.

Market and technology overview

The global market for uranium and derivative products is large and growing, driven by continued nuclear builds in Asia and continuing technological innovation. Market opportunities include:

- The market for uranium is expected to reach $14 billion by 2020 (5 percent CAGR), with 23 percent margins.
- The conversion, storage, and reprocessing market will reach $8 billion conversion by 2020 (2 percent CAGR), with 5 to 10 percent margins.

New technologies for mining include: methods for efficient and environmentally friendly extraction of uranium ore, refinement, and fuel-rod production; nuclear base-load matching using load control and energy storage; reclamation of spent nuclear material; waste management and conversion to revenue products and disposal; radiation, health, and safety monitoring technologies; and early detection and response.

Canadian advantage

Canada has the third largest uranium reserves in the world (and the second highest for extraction), largely mined through heap leaching of low-grade ore.

CAMECO is the world's largest publicly traded uranium mining company with revenues of $2.4 billion (2011) and 3,300 employees. It accounted for 16 percent of the world's uranium production in 2011. Its activities include uranium mining, fuel services (refining, conversion, and fuel manufacturing), and partial ownership of four nuclear reactors owned by Bruce Power Limited Partnership. CAMECO has controlling ownership of the largest, highest-grade reserves in Canada.

Investment thesis

Canada's opportunity is to maintain its position as a top uranium miner by pursuing cost-reducing technologies.

RENEWABLES AND CLEAN ENERGY: NUCLEAR TECHNOLOGIES

Technology areas under consideration

Considered in this report are new reactor construction (reactor, containment, power generation, and utilities), reactor decommissioning (nuclear waste handling and worker safety), advanced fuel cycles, small-medium nuclear reactors, designing and manufacturing small modular reactors, and nuclear fusion.

Market and technology overview

New nuclear power plants are planned in China, Russia, India, and Turkey, with new builds approaching $400 billion in 2020. Most projects are government-backed and focused on passive safety systems. Canadian government involvement is needed to establish diplomatic, trade, and export relations.

The market for retiring and refurbishing reactors is also expected to grow. Approximately 45 to 50 GW will be retired in the United States and Japan by 2030; $0.5 billion to $2.0 billion is required to refurbish each reactor. The market for enrichment is expected to reach $10 billion by 2020 (2 percent CAGR) with 19 to 40 percent margins.

The technology for modular nuclear plants is still immature, and most technology leaders are outside Canada. There has been some progress developing small and medium-sized reactors within Canada for eventual export. Nuclear fusion technology is still in the early R&D stage, with multiple large efforts across the United States, Asia, the European Union, and Canada demonstrating theory but not commercial viability. While there are no major roadblocks, significant engineering hurdles exist.

Canadian advantage

Canada has a large nuclear technology base centred on the Candu reactor. Nuclear energy is a $6.6 billion per year industry in Canada and generates $1.5 billion in federal and provincial revenues through taxes (Canadian Energy Research Institute, 2008).

Candu Energy reactors are 10 percent of the worldwide installed base. Candu is a heavy-water design, trading the cost of heavy water (23 percent of capital costs)

for the ability to use enriched uranium as a fuel. It is also possible to use other fuels (thorium, plutonium), as well as spent fuel from other reactors. The Candu 6 reactor is a Gen III passively cooled reactor design that is attractive in this post-Fukushima environment.

Candu Energy (a SNC-Lavalin subsidiary) has the licence to the Candu design. It is engaged in several projects with Romania, China, and Argentina, and it has proposals in several other countries. Projects include new reactor builds (primarily steam generation and reactor components), life extensions, development of advanced fuel-cycle reactors (which can use recycled uranium and thorium), and testing the Candu design in plutonium disposal. Many projects are in the proposal stage, where Canadian government involvement (e.g., diplomatic) is necessary to maintain Canadian competitiveness. Aiming to move up the value chain for greater profitability in enrichment, CAMECO has entered a joint venture with GE and Hitachi to develop laser enrichment technology.

Canada continues to develop technologies that increase the efficiency and environmental friendliness of nuclear plants, including:

- Regeneration of contaminated wastewater (Kinectrics, Tyne)
- Storage of waste in getter systems (Darlington TRF, AECL, SRB, Shield Source, and Kinectrics).

For refurbishment, Canada has a robust economic market (spending $10 billion to $15 billion on refurbishment up to 2025), but this does not create significant net domestic economic value since it is spent to keep existing plants operational. For Canada, the export market for refurbishments, decommissioning, and maintenance is not large primarily because a number of large global companies already service this business and because Canada's heavy water technology is seen globally as a niche.

Canada has shown some support for the General Fusion reactor effort with direct funding from SDTC. The project has attracted a total of $58 million in seed funding (including venture capital) since 2007 and may demonstrate an exothermic reaction in 2014. However, commercialization is likely more than 20 years away, and foreign investment in nuclear fusion has far exceeded the investment in General Fusion (e.g., the ITER International Nuclear Fusion Project exceeding $20 billion in global investment).

Investment thesis

Canada has little opportunity for new reactor builds based on the Candu technology, and only limited opportunity to capture the nuclear reactor refurbishment and decommissioning markets and to continue long-term reactor research. At present, 29 Candu reactors are in operation, including 13 in India. Each of the reactors will require refurbishment and/or decommissioning at a cost of approximately $0.5 billion to $2.0 billion each.

If Canada is to pursue new nuclear reactor sales via the recently privatized Candu Energy Inc., it will require some government involvement in reactor sales to foreign countries, as well as new reactor technology development to face increasing international pressure from new, non-heavy water designs.

Small/medium modular nuclear plants and nuclear fusion also have domestic and export potential, but will require longer-term (>10-year) investments to verify safety and longevity, and will need to prepare themselves for strong competition from companies in the European Union, the United States, and Japan.

For fusion, the technology developed by General Fusion, while exciting, either requires far greater public investment (comparable to the billions invested elsewhere) or is best to be left to unfold as either a successful disruptive technology or one that is not viable.

RENEWABLES AND CLEAN ENERGY: BIOENERGY

Technology areas under consideration

The technology areas considered here fall into three categories: 1) biopower (electricity from biomass); 2) bioheat (heating from biomass); and 3) biomass collection, processing, and densification.

Market and technology overview

The biopower market is fast growing and regionally driven. Most of the growth is in the European Union due to renewable regulatory commitments of 20 percent of generation by 2020 and a desire for greater domestic energy security. Biomass is a renewable low-carbon feedstock that can replace coal as a provider of peak power, and it can be installed at the scale needed to meet the European Union's targets.

There is a small market for biopower today, consisting mostly of decentralized power generation in industrial facilities, such as pulp and paper plants, using refuse for electrical generation to reduce costs. Global expenditure will peak at $100 billion to $200 billion in 2020 and decline thereafter, assuming biopower feedstock remains readily available. One potential bottleneck is that as no commitments to long-term feedstock sourcing contracts have yet been made, there is uncertainty about long-term sources and pricing. Canada has capacity for wood pellet production, but is currently exporting less than $500 million in wood pellets to Europe. In their attempt to diversify from coal as a power source, China and (to a lesser extent Korea) are driving some of the biopower growth.

The technology for extracting power from biomass is mature and similar to that used in thermal coal power plants. Collection and processing are capital-and energy-intensive, so innovation and R&D in these areas, especially torrefaction and other densification technologies, could have a large impact on the overall cost. Gains in other areas, such as thermal combustion and combined heat and power (CHP) technologies, will likely be smaller improvements in process efficiency.

Bioheat employs combustion and steam generation technologies similar to biopower in technology although, like district heating, usually at a smaller scale. Although public opinion is mixed about plant versus tree-based bioenergy, support for using agricultural or forestry residues for power instead of landfill is generally positive.

Canadian advantage

Canada has large forests and extensive low-value bioenergy feedstock, such as mill waste and beetle kill. This generated only modest value creation in exporting densified pellets since whole-tree harvesting for pellet export contributes little value to Canada and Canadian competitiveness. As Canada is a recognized world leader in forestry management, collection, and processing technologies, there may be greater value in smaller exportable technologies like CHP package units.

Several small Canadian companies are innovating in this sector, including Nexterra in British Columbia that has installed a number of units in forest sector industrial facilities where it is economic, and it has built a system at the University of British Columbia using advanced gasification technology. CHP is also attractive for heating capacity, since bioheat is one of the few renewable

replacements for natural gas, and heating accounts for almost half of global energy use.

Investment thesis

Canada can increase the cost-effectiveness of exporting pellets derived from agricultural and forestry residues by developing energy-densifying pretreatments, such as torrefaction and pyrolysis (the Canadian company Ensyn is a global leader in pyrolysis technology), while reserving whole-tree harvesting for higher-value products (see section on biofuels and biorefineries). Value from the export of forestry management, collection, and processing is unlikely to increase from its current level. Thus, niche markets with small, distributed systems close to local biomass feedstock are the best market for Canadian bioenergy and bioheat technologies globally, as they are for CHP

RENEWABLES AND CLEAN ENERGY: BIOFUELS/BIOREFINERY

Technology areas under consideration

The technology areas considered here fall into four categories: 1) next-generation lignocellulosic ethanol; 2) production of biologically derived drop-in fuels; 3) biogas (methane from biological sources); and 4) production of value-added biorefinery products (green chemistry).

Market and technology overview

Biofuels are a large and growing market, driven by the demand for high-energy-density, renewable transportation fuels, greater energy security and less reliance on imported petroleum. With its RFS2 (renewable fuel standard) mandates, this makes the United States a key market for biofuels.

First-generation biofuels are traditionally produced from corn (as in the United States) or sugar (as in Brazil). However, using food crops as transport fuels is growing increasingly unpopular. This has spurred interest and innovation in second-generation biofuels produced from agricultural or woody biomass residues.

In 2010, bioethanol production was 98 GL globally, 51 GL of which was produced in the United States, whereas biodiesel production was 23 GL with 12

GL of it produced in the European Union. By 2020, bioethanol production is projected to increase to 260 GL, and biodiesel production to 64 GL. For cellulosic ethanol, demand in the United States is projected to rise to 16 GL to meet its RFS2 mandates by 2022, which means that 360 new advanced (cellulosic) plants will be necessary. Only 30 new first-generation ethanol plants are likely to be built in the same time frame.

Although many efforts have focused on bioethanol production, several companies are exploring the viability of producing high-value products from low-value cellulosic biomass (i.e., a biorefinery). As in a petroleum refinery, a significant portion of value stems from low-volume, high-value products like pharmaceutical feedstock. In this model, even though the cost of producing bioethanol from biological feedstock may be greater than from petroleum, it can still add to the biorefinery's profitability.

Although using plants and trees as a substitute carbon source for petrochemicals is attractive, the technology for biorefining is still nascent. Granted, some thermal technologies can integrate CHP (bioenergy) gasification with biorefining, remove some high-value fractions of syngas from the CHP stream, then process this stream to produce a value-added bioproduct. However, there will be no definitive proof that biomass gasification technologies generate value-added bioproducts until the chemistry, catalytic behaviour, and value of biorefined syngas are better understood. Also, while biorefinery may produce drop-in products for existing petrochemicals, no one knows if its greatest value may lie in producing new feedstocks for embryonic processes that will take time to develop.

Feedstocks for biofuels and biorefineries vary greatly in availability and difficulty of processing. Agricultural residues such as corn stover, husks, and grass residues are the easiest to process and are readily available in the United States where most cellulosic biofuel plants are being built. More abundant but difficult to source and process are woody biomass residues, such as timber processing and forest management residues. Woody biomass feedstocks are the likeliest candidates for biofuel and biorefinery production in Canada but, to compete with agricultural residues, they will have to be collected and processed more efficiently. Since whole-tree plantations cannot compete with fast-growing tree plantations, such as eucalyptus in the United States, new technologies will be needed to unlock value for biofuel and biorefinery production from woody feedstock, likely with enzymatic or metabolic processes. These R&D goals are probably more than 10 years away because advanced lignin chemistry is needed.

Biogas, both from agricultural and livestock residues, has been used for decades in small decentralized areas. However, the low cost of natural gas resulting from the North American shale gas boom has made biogas less attractive.

Canadian advantage

Canada has large supplies of forest and agricultural residues. The majority of forest lands in Canada are under the control of Crown corporations in the form of Forest Management Agreements (FMAs) granted by provincial governments. This is in contrast to the predominant private ownership of forests in the United States that gives Canada the advantage of being able to offer long-term contracts on feedstock prices (like a FIT) that are unavailable in the United States.

Although much of the $3 billion capital expenditure on biofuels production will be based in the United States, Canada has an opportunity to capture early-stage commercialization of biofuel technologies by offering long-term feedstock sourcing contracts and other mechanisms, thereby attracting companies that need reliable sources of feedstock for their commercial-stage pilot plants. These plants require large, local investment in design, manufacturing, and operations capability, all of which are crucial to Canada's long-term competitiveness and ability to capture value.

Canada espouses government collaboration and supports biorefinery research through NSERC Industrial Research Chairs. In addition, Canada has several companies with notable technology and progress, among them Iogen, Ensyn, Lignol, and Enerkem. Large pilots are underdevelopment in the United States and the European Union by POET, Greenfield Ethanol, and MG. Canada's small-scale gasification technology for CHP (e.g., Nexterra) can replace small-scale biorefinery by stripping larger amounts of high-value syngas from gasified forest, pulp and agricultural residues.

Investment thesis

Canada's opportunity in biomass lies in exporting less low-value biomass for refining elsewhere (e.g., the United States) and developing a domestic capability to produce, refine, and export more high-value bioproducts. Canada's strong regulatory control over its forest stock makes adopting emerging foreign technologies an attractive option for cellulosic ethanol production. By investing in long-term (10 years or longer) R&D today, Canada could take a lead role in developing technology (i.e., as part of a suite of products created in a biorefinery)

that would enable it to become both a producer and an exporter of high-value bioproducts and technology. In the short term, Canada could consider investing in R&D to integrate biorefinery with CHP gasification technologies, two commercially viable process that may offer greater value and competitiveness if integrated.

RENEWABLES AND CLEAN ENERGY: CONVENTIONAL HYDROELECTRIC

Technology areas under consideration

The technology areas considered here fall into two categories: 1) conventional turbines and generators; and 2) construction, management, and refurbishment of conventional hydroelectric projects.

Market and technology overview

The conventional hydropower market is one of slow growth but high value, with $420 billion in global capital expenditure projected for 2020. The top three exporters of turbines and generators are in Europe: Alstom in France, Andritz in Austria, and Siemens in Germany. However, cost pressure from BRIC companies is increasing, mostly due to their success developing domestic projects but increasingly as a result of their greater involvement in export markets.

Canada is a net exporter of electricity to the United States; in 2008, it exported $3.8 billion and imported $1.3 billion.

Canadian advantage

Canada has large domestic hydropower resources and is the third largest producer of hydropower globally. It is a net exporter ($2.5 billion in 2008) of electricity to the United States and has significant project management engineering expertise (e.g,, SNC-Lavalin, Hydro-Québec, and Hatch Energy).

Examples of Canadian companies active in hydropower include:

- Hatch Energy – designed more than 40,000 MW of hydropower around the world since 1924, including design and construction management, risk assessment, regulatory management, efficiency testing, dam safety, and due diligence for asset transfer

- Canadian Hydro Components – designs hydroelectric turbines for low-medium hydro projects
- Coppex Power Technologies – produces winding wire for transformers, generators, and motors, and offers a quick turnaround and customization
- Unit Electrical Engineering – manufacturer with a specialty in hydro electrical equipment, control systems, and balance of plant.

The relatively low cost of hydro electricity has attracted many energy intensive industries – such as smelting, aluminum production, and manufacturing – to Canada.

Investment thesis

Canada's opportunity lies in its ability to continue attracting power-intensive, economically strong industries and export surplus power to the United States. Another opportunity for Canada is to increase the export of hydroelectric construction and project management services.

RENEWABLES AND CLEAN ENERGY: UNCONVENTIONAL HYDRO/MARINE

Technology areas under consideration

The technology areas considered here fall into two categories: 1) run-of-river and low-head hydropower (hydrokinetic); and 2) tidal and wave hydropower.

Market and technology overview

The unconventional hydro market is mature in some areas (e.g., run-of-river hydropower) and still nascent in other areas (e.g., hydrokinetic). New technologies are on the horizon.

Run-of-river hydropower is produced in countries around the world, but since it was developed in niche regions with domestic technology, it is very fragmented. Output power has typically been too small to attract larger companies, but this is changing as a result of industry consolidation and increasing investment from large conventional hydroelectricity companies.

Tidal and wave electricity, also regional developments, are growing slowly globally. Most feasibility studies using existing technologies have determined that tidal and wave electricity are too costly for the amount of power produced. However, disruptive technologies may play a role in future.

Hydrokinetic power – smaller, low-head turbines submerged in rivers – has the potential to be a large global technology, with some studies showing 100 GW of global potential, often in rivers close to urban areas. Several small, private R&D projects are piloting their technology, and interest is growing in large energy companies speculating that hydrokinetic power is a disruptive technology capable of changing the global electrical landscape within 10 years.

Canadian advantage

Canada has large tidal, wave, and hydrokinetic resources and technical expertise in conventional hydro. This engineering expertise in turbine and generator technology is transferable to unconventional hydro. There are several small companies in Canada, including: Clean Current Power Systems, which has partnered with Alstom, a leading turbine manufacturer; and RER, which has a promising TREK turbine design. Small Canadian companies have a wide range of relevant intellectual property and working pilots that have attracted the attention of large multinationals. However, international technology development is significant, including 70 preliminary permits for hydrokinetic power in the United States alone, and there is some activity in EU-China partnerships, which makes it difficult for Canada to compete in this arena.

Investment thesis

Canada's opportunity lies in commercializing and exporting unconventional hydroelectric technologies and services. Hydrokinetic turbines probably have the highest export potential since urban areas near rivers are widespread, but it may be difficult to prevent copying or competition from large companies. To encourage fast adoption and to maintain market share, Canada needs to immediately scale up pilots and to focus on reducing the cost of small units.

DISTRIBUTION: SMART GRID (AMI, HAN, DEMAND MANAGEMENT, APPLIANCES)

Technology areas under consideration

The technology areas considered here include: automated meter integration (AMI); home area network (HAN); demand management/response; storage, appliances; program management; and financial services.

Market and technology overview

The global smart grid market is large ($41 billion in 2011) and rapidly growing, but it is highly commoditized at most points in the value chain.

The market for smart grid infrastructure equipment and products is driven by the long-term shift of utilities worldwide to smart grid distribution systems that increase efficiency and capacity. The market is a mix of large global and regional suppliers and, outside Canada, highly fragmented utilities markets.

The equipment and network infrastructure value chain is largely commoditized. Upstream components, such as meters and switches, are mostly constructed from existing technologies. With the exception of power electronics in transmission/distribution (discussed in the next section), they are largely commoditized as well, with several large global companies, such as Siemens and General Electric, producing products for the global market. Opportunities exist for entry downstream in the integration of PV, storage, and EV-charging infrastructure and smart grid management, where hardware, software, and control algorithms have yet to be proven at scale. Opportunities also exist in end user products (e.g., smart thermostats, smart-grid-enabled appliances), but, like many consumer electronics markets, these are expected to be low margin with many large global competitors.

Technology adoption tends to be slow because of risk aversion the long regulatory approval cycle, and the differing needs of individual utilities. Major technical issues in smart grid pilots include:

- It is difficult to estimate system costs, and overruns are highly publicized.
- Standards in many cases are not yet in place and can cause delays and bottlenecks.

- Pricing and distribution models are difficult to evaluate, except at scale, and therefore are risky.
- Integration of local power sources and large drains (e.g., PV, storage, and EV) is still experimental.

Canadian advantage

Canada has some domestic companies downstream in the value chain and a less fragmented utilities market than that of the United States but few Canada-based global companies.

An advantage that has led to early adoption is that, in the majority of provinces, utilities are vertically integrated Crown corporations with some investor-owned distributors. Smart-meter rollouts in Ontario that were completed in 2010 gave Tanalus and other Canadian companies an early advantage.

Siemens recently signed an agreement with New Brunswick Power to develop a comprehensive smart grid program for the province. The program is part of New Brunswick's Power RASD (reduce and shift demand) energy blueprint and will include smart thermostats, appliances, dashboards, thermal storage, and an R&D centre with 40 new jobs.

Canada has several smart grid startups but no clear winners:

- Tanatlus – smart grid communications
- Clevest – utilities automation
- NxtPhase – T&D, bought by Alstom
- Potentia – solar generation
- Ozz – rooftop solar
- Energate – home energy management/demand response
- Power Measurement Limited – metering
- Pulse Energy – energy information software
- Ruggedcom – harsh-environment networks, acquired by Siemens.

Investment thesis

Canada could gain domestic benefits by adopting smart grid technologies early and attracting foreign companies willing to invest in Canadian markets through federal, provincial, and municipal partnerships.

Early adoption could lead to lower domestic power prices and a higher utilization of existing resources. Power utilities are concentrated on EV-charging infrastructure, speeding domestic development.

As demonstrated by the New Brunswick-Siemens collaboration, integrated utilities can attract manufacturers and local development of smart grid appliances and equipment and reap gains in utility efficiency. Additional value may be captured if smart grid manufacturing is brought to Canada and if downstream technologies such as PV and vehicle integration can be developed and retained in Canada for export.

DISTRIBUTION: SMART GRID (POWER ELECTRONICS IN T&D)

Technology areas under consideration

The technology areas considered here are power electronics used in distribution: transformers, high-voltage DC (HVDC), flexible AC transmission systems (FACTS), fault detection/isolation/resolution, switching, sensing, volt-var, PV, and wind power conversion. Not included are power electronics in vehicles (this specialized supply chain is described in the section on EVs) and consumer electronics (which are not part of large-scale power distribution).

Market and technology overview

Power electronics in smart grid transmission and distribution is a large and growing market marked by continuous innovation and the possibility of disruptive change on the horizon. Power electronics used in electrical transmission and distribution are expected to grow to $10 billion by 2020, driven by wind and PV demand. Transmission and distribution markets will experience longer-term growth with the introduction of thyristor replacements.

Silicon carbine (SiC)- and gallium nitride (GaN)-based transmission components are still at an early stage (laboratory and limited production) but are seen as potentially disruptive. SiC chip production will likely occur in large fabrication

facilities, but power module design is still open to innovation and new applications.

Canadian advantage

Most manufacturing and innovation in power electronics occurs outside Canada, mainly in the United States, the European Union, and Japan, and is driven by large capital investments and strong consumer and auto industries.

Large companies dominate the upstream value chain because of high fixed costs in semiconductor manufacturing and module packaging. Many companies find horizontal and vertical integration advantageous and are actively expanding their reach and capabilities. Development in many countries is driven by large consumer electronics; PV, wind, and EV industries are also driving development in some countries.

Canada has a background in telecom electronics design (e.g. Nortel) and has facilities like the Manitoba Hydro High Voltage Test Facility for testing high voltage power electronics designs.

Investment thesis

Canada has an opportunity to develop and export niche applications (e.g., specialized high-power switches and sensors, integration into utility systems) whose markets are still fragmented and not served by the majors.

The potential for long-term growth in Canada's GDP is limited, as major manufacturers will compete with or acquire rapidly growing technologies.

BUILDINGS AND COMMUNITIES: ADVANCED LIGHTING

Technology areas under consideration

The technology areas considered here are LED lamps, ballast/optics, luminaire, and external controls (including system-level controls and automation). Also included are active power management systems for buildings and alternative lighting techniques (daylighting, light pipes). OLED and flexible LED displays are not included.

Market and technology overview

The global market for advanced lighting is large, with particularly strong growth in LED lighting. The LED lighting global market is expected to grow to $38 billion by 2020, driven by the replacement of incandescents (both voluntary and mandated by regulation).

Upstream chip and packaging are becoming commodified and consolidated, areas in which China and Taiwan have large cost advantages and capacity build-out. The luminaire market is fragmented but is served by many large companies, including Phillips, Osram, GE, and Zumtobel.

Niche technologies are emerging downstream, including active power management (fluorescent/LED dimming at a building-wide level) and unconventional lighting (light-pipe/daylighting).

Canadian advantage

Both the Chinese and Taiwanese governments have subsidized the growth of metal organic chemical vapour deposition (MOCVD) capacity, thus increasing global supply and lowering costs. Unless Canada is prepared to make or attract large investments in LED semiconductor manufacturing capability, it will not be able to compete in the upstream supply market.

The downstream market for LED applications (e.g., specialized luminaire fixtures) is still highly fragmented, and Canadian companies will have to be competitive to succeed in this cost-driven manufacturing market. It may be possible for Canadian players to enter applications that require advanced design and manufacturing optimization (e.g., quality control and scaling).

Investment thesis

Canada can stimulate domestic luminaire growth through large-scale public LED adoption programs that support closer working relationships among local manufacturers, Canadian contractors, and government.

Another opportunity lies in exporting outdoor luminaires to China to meet the demand created by the Chinese government's streetlight LED pilot that targets 65 percent penetration by 2015. To take advantage of this opportunity, Canadian companies could partner with local Chinese engineering firms with close government relationships, particularly general engineering firms, as they are

further downstream. Procurement is a major cost disadvantage for Canadian companies operating in China, so it is likely that, to be cost-competitive, they would have to manufacture in China, which would limit the number of Canadian jobs and the GDP impact.

BUILDINGS AND COMMUNITIES: ENERGY-EFFICIENT BUILDINGS

Technology areas under consideration

Considered in this report are four areas of energy-efficiency in buildings: 1) advanced windows (raw materials, assembly, services); 2) HVAC (manufacturing, services), including small-scale CHP; 3) emerging technologies in building efficiency (including integration with PV and smart grid); and 4) prefabricated energy-efficient houses.

Market and technology overview

The global windows and HVAC markets are large ($69 billion in windows and $130 billion in HVAC in 2011) and growing moderately, driven by new residential and commercial building construction in Asia.

Energy efficiency in buildings has the potential to create large energy savings; for example:

- Most residential housing is poorly insulated, with windows accounting for 10 to 20 percent of energy losses.
- Active window coatings can reduce life cycle costs by 30 to 45 percent over a 30-year period.

Emerging technologies in building efficiency include:

- Innovations in thermal insulation that reduce space heating loads leading to smaller/cheaper HVAC systems
- Low-cost, real-time, consumer energy usage feedback systems
- Low-cost, smart commercial building energy management systems
- Seamless integration of solar thermal and PV with HVAC
- Building integrated PV/solar thermal (BIPVT)
- Compact thermal and electrical storage components

- Compact/efficient housing/light commercial micro-generation systems
- Compact, turnkey, local, smart, municipal-distributed energy networks (systems and service industry), including distributed co-generation and district energy systems
- Integrated municipal-based energy investment decision support tools
- Active windows and advanced window coatings
- Liquid desiccants for humidity control.

A large number of small and medium enterprises (SMEs) serve the building energy-efficiency markets. The market is highly competitive, so most businesses do not have the resources for R&D. They also compete with products from the United States that tend to be designed for the US rather than Canada's climate, further decreasing energy efficiency.

The regulatory landscape is also fragmented (discussed further in Section C), with municipal, provincial, and federal building efficiency varying across regions.

The windows value chain is consolidated at the raw materials stage (a few global-scale glass manufacturers supply the market), but downstream manufacturing and assembly markets are highly fragmented.

Prefabricated housing where energy-efficient technologies are integrated into the house in the factory are a nascent market, with some manufacturers offering such houses for shipment around the world at low volume.

Canadian advantage

In windows, Canada has one large window manufacturer, Willmar Windows is a Canadian-based subsidiary of Jeld-Wen, which itself is one of the largest window manufacturers in North America. Onex, a large Canadian private equity firm, has a controlling interest in Jeld-Wen.

Canada is also a leader in net-zero energy and energy-efficient building initiatives.

- The Net-Zero Energy Home Coalition promotes NZEH Ready and NZEH standards.
- The Canada Mortgage and Housing Corporation sponsored the Equilibrium Sustainable Housing and Communities Competitions.

- NRCan's ecoENERGY Retrofit – Homes program (2007-2012) gave grants to homeowners to improve energy efficiency.
- Canada has several pilot homes, including EcoTerra House, EcoPlus Home, and the net-zero, passive house.
- Energy Star prefabricated homes were introduced by Mandala Custom Homes in BC and include LED/CRL lighting, HRV, skylights, solar tubes, ICF foundation, locally sourced building materials, no-VOC paints and finishes at $60 to $90 per square foot.

Investment thesis

Canada's opportunity lies in capturing the domestic benefit of increased building efficiency early by promoting and adopting net-zero energy housing and buildings standards, while exploring the viability of exporting its technologies to global markets.

ENERGY-INTENSIVE INDUSTRIAL PROCESSES: WATER

Technology areas under consideration

The industrial water technologies considered in this report fall into three categories: 1) distribution (e.g., pipes, pumps, valves) and efficiency (e.g., drip irrigation) technologies; 2) filtration and chemical technologies that treat industrial or municipal water; and 3) construction, operation, and maintenance services for industrial or municipal water treatment.

Market and technology overview

The relationship between water and energy is significant. For example, energy projects account for 27 percent of water consumed outside of agriculture. The industrial water market is a very large, moderately growing global industry. In 2011 the global market for water equipment and services was $515 billion, with equipment accounting for $110 billion. Many areas of the equipment value chain are technologically mature, as are most distribution (e.g., pumps) and chemical technologies (e.g., chlorine disinfection), and are becoming increasingly commoditized. The highest growth is in membrane and filtration technologies, which is an $18 billion market with a 10 percent growth rate. New membrane and filtration technologies are hindered by economically conservative (and often

public) water utilities that are usually reluctant – or unable – to spend public money on unproven technologies. This reluctance to adopt new technology has beleaguered innovation, since bringing a product to market requires lengthy pilots and standards testing.

Canadian advantage

Canada has several promising technology companies that have attracted the attention of global investors. Canadian companies are strongest in membranes and filtration equipment – over 2,000 units are employed in Ontario alone. This is also the fastest growing market. Zenon, which was acquired by GE Water, is a global market leader in membranes with approximately 25 to 30 percent market share, and Trojan Technologies, acquired by Danaher Corp., is the market leader in ultra-violet filtration for clean and wastewater. There is also significant startup activity in this market (e.g., Xogen).

Canada demands high water treatment standards as the social licence to operate in oil, gas, and mining. This has spurred innovations in advanced wastewater treatment technologies (e.g., ProSep), advanced pipeline monitoring, and leak detection.

Investment thesis

Canada has several opportunities in this area because of its expertise in water treatment and purification and wastewater management, as well as its strict regulatory climate:

- Grow and retain its existing strength in membrane and filtration technologies, which can be exported to fast-growing global markets in water treatment products
- Export advanced wastewater treatment technologies, expertise in oil, gas, and mining, and advanced monitoring and leak detection technologies
- Attract foreign companies, such as Siemens and Viola, to Canada to test products for the North American market.

ENERGY-INTENSIVE INDUSTRIAL PROCESSES: WASTE TO ENERGY

Technology areas under consideration

The waste-to-energy (WTE) technologies considered in this report fall into three categories: 1) the equipment and associated technical components for the conversion of waste (in this report, municipal solid waste) into energy (electricity and heat); 2) the engineering and design of WTE plants; and 3) the operation and maintenance of WTE plants.

Market and technology overview

WTE is a moderately sized market dependent on municipal waste production, landfill tipping fees, energy prices, and regulations. Several regionally established technologies are in use and some potentially disruptive technologies are on the horizon. The global market is modest, generating $4 billion in revenue in 2011, including electrical generation and tipping fees. The global equipment market is expected to grow significantly, to $77 billion in capital expenditure, by 2014.

Technologies range from commercial incineration and anaerobic digestion WTE plants to emerging technologies, such as thermal and plasma gasification, which are currently operating at pilot scale. A serious bottleneck for WTE technology development and commercialization is that municipal utilities are often reluctant to invest in risky new technologies. An additional barrier to adoption is the negative public perception of incinerators and waste treatment plants.

Currently, WTE is economical in Europe, where high tipping fees and strongly enforced separation of municipal waste streams into biological and other materials enable incinerators to operate efficiently. This is the primary reason that Europe is the global leader in WTE technologies and utilization.

Canadian advantage

Canada has some leaders in emerging WTE technologies, but it is unclear whether it can become a technology export leader. Some domestic value exists in WTE use, but it is limited by the low cost of electricity in Canada and a weak recycling and municipal waste separation infrastructure. Thus, the majority of value would be in exporting technologies to the United States and the European Union. Startup activity in Canada is significant, including Plasco and Enerkem, which are both demonstrating pilot work and looking to expand.

Investment thesis

Canada's opportunity is to develop and use Canadian WTE technologies domestically to demonstrate scale-up and prove exportability. A second opportunity is to develop disruptive WTE technologies for export to the United States and the European Union.

ENERGY-INTENSIVE INDUSTRIAL PROCESSES: ENERGY-EFFICIENT PROCESSES

Technology areas under consideration

Considered in this report are energy-efficient processes for a variety of industries including chemicals, steel, mining and other metals, pulp and paper, cement, and agriculture.

Market and technology overview

Industrial processes represent a large fraction (32 percent) of global energy demand. Growth in demand is moderate (1.1 percent per year), driven primarily by China.

Most large industrial processes are well-established but, in many cases, incremental changes across process steps (e.g., system integration across products, minimization of waste streams, load management, motor torque, and speed optimization) can lead to energy savings of 20 to 30 percent. Many of these improvements are possible because of improvements in real-time instrumentation, monitoring, and data analysis systems.

The main bottleneck to the adoption of higher-efficiency processes tends to be risk aversion and short-term cost. In many cases, efficiency improvements require the reconfiguration of existing, productive process lines, and the process owner is understandably reluctant to take on the immediate loss in productivity, the capital cost of new equipment, and the technological risk for a long-term and sometimes small improvement in energy efficiency. In these cases, external mechanisms such as incentives and regulations may be necessary to trigger adoption.

In addition to incremental improvements in process efficiency, R&D into potentially disruptive processes in many industries is ongoing. For example:

- Steel – researching coke-less processes

- Mining – searching for revenue products from waste
- Cement – researching refuse-derived fuels, carbon sequestration, and low-CO_2 concrete chemistry
- Paper and pulp – researching new products, including fabrics, fuels, and high-value biorefinery products
- Across all technology areas – researching CHP and waste heat recovery.

In many of these areas, R&D is conducted by industry consortiums and universities.

Canadian advantage

Canada has significant steel, mining and metals, pulp and paper, cement, and agriculture industries today and has been building capacity in applying process integration techniques that can yield significant savings. However, the United States and the European Union are the global market and technology leaders in energy-efficient processes and potentially disruptive processes.

- Many energy-efficient processes use US- or EU-developed technologies, and some manufacturing is already moving to Asia to satisfy regional demand.
- The United States and the European Union are viewed as the providers of technology and equipment leaders in energy-efficiency equipment and processes.

Canada has several small companies with innovative technologies, particularly in process and systems control:

- Energy consumption avoidance with motor control (CVT, Bestech, MTI, Rail-Veyor)
- Waste reduction and optimized process control (SBI, Yava, Kemetco, Nichromet)
- Real-time monitoring and control (Tenova, WHL, MineSense, Nimtech, Pavac)
- Systems design (Econoler).

Investment thesis

The greatest beneficiaries of improved process efficiency are Canadian companies, which can lower costs and become more competitive in global markets. The government may have a unique role to play in lowering the barriers to process adoption through capital expenditure incentives and efficiency regulations. In addition, the government could continue to encourage long-term research and development into disruptive processes.

Some export potential exists, but it is limited by two factors. First, most companies view processes and process improvements as strategic trade secrets that they are unwilling to share with competitors. It may be possible to export equipment associated with new processes, but this is vulnerable to copying by Chinese competitors.

TRANSPORTATION: CNG/LNG FLEETS

Technology areas under consideration

Considered here are natural gas vehicles (both LNG and CNG varieties) and natural gas refueling infrastructure.

Market and technology overview

CNG/LNG adoption in heavy vehicles will be driven by inexpensive natural gas in North America but only after 2020. CNG/LNG is predicted to become a large part of the truck fleet in North America, driven by economics and by the lack of competitive low-carbon emissions drivetrain technologies for trucks. CNG/LNG is not expected to gain appreciable share in light vehicles given the competition with electric technologies.

The lack of a refueling infrastructure prevents widespread adoption. Currently, CNG is being used in short-range fleets, whereas LNG is favoured for long-haul fleets where longer ranges and faster refueling are required and higher capital expense is acceptable.

Canadian advantage

Canada has large natural gas fields that can provide natural gas domestically at low cost. Using this low-cost resource as a substitute for more expensive diesel will generate value for the Canadian economy.

Canada also has a major natural gas truck engine technology company. This is a strong advantage because diesel engines, unlike gasoline engines, require re-engineering to convert to natural gas. Westport is the owner of High Pressure Direct Injection technology, which enables diesel engines to run on natural gas (by injecting a small amount of diesel), as well as LNG and ignition technologies. Westport has also formed a partnership with the US truck engine company Cummins Inc. and others to build medium- to heavy-duty natural gas engines, tanks, and LNG systems. In addition, other Canadian firms are providing the technologies required for natural gas vehicles, including Calgary-based Dynetek, which manufactures advanced fuel storage cylinders.

The adoption of natural gas for vehicles has faced two barriers in the past – building natural gas infrastructure and large-scale conversion/adoption of the vehicles themselves. The high volatility of natural gas prices, and other reasons, discouraged infrastructure development and left natural gas vehicle owners without a refueling infrastructure.

With natural gas prices projected to stay low in the long term in North America, large natural gas companies have shown a willingness to invest in infrastructure. Vehicle owners who have had poor experiences in the past and are reluctant to invest in the vehicle premium required to upgrade to natural gas are the remaining barrier.

Investment thesis

Canada has a strong opportunity for the long-term development of a CNG/LNG truck fleet in North America. The main benefit would be domestic economic value created from using natural gas as low-cost transportation and industrial fuel/feedstock.

A second opportunity is to export natural gas engines and vehicles to the United States when it eventually adopts this technology.

TRANSPORTATION: NEXT-GENERATION AUTOMOBILES

Technology areas under consideration

Considered in this report are: 1) the electric vehicle (EV) drivetrain (batteries, power electronics, motors), body (lightweighting), and other components; 2) the fuel-efficient vehicle drivetrain (advanced engine technologies, braking/ regeneration, and storage); and 3) EV recharging network/infrastructure. Fuel cell, diesel, and LPG/CNG vehicles are not included.

Market and technology overview

The next-generation automobile market is large and continuously evolving, with improvements in internal combustion engines (ICEs) and in EV technologies driving efficiency and cost gains.

In the near term, ICEs will continue to be in demand through 2020, and mass adoption of EVs is expected by 2050. Specifically, in 2030, 60 million gasoline and 22 million plug-in hybrid electric vehicles (PHEV) are predicted to be sold. In 2050, the vehicle mix will shift to 14 million gasoline and 87 million PHEV, with high adoption rates of battery electric vehicles (BEV) and fuel cell vehicles (FCV) in China driven by low electricity and high petroleum prices.

EV and ICE technology is continuously evolving. All companies are actively researching improved battery, power electronic, motor, and materials technologies. Some disruptive technologies, like silicone carbide (SiC) in power electronics, are on the horizon. Recharging technology is mostly waiting for standardization and growth in the number of electric vehicles. In all technology advances, large suppliers with established relationships are favoured.

One long-term play that has been identified is in rare earths, of which Canada has large deposits. Most rare earths are used in EV motor magnets and polishing, and demand for rare earths is expected to continue to grow 11 percent per year through 2015, with China as the primary consumer (70 percent).

This approach carries significant technological and market risks. Rare earth mining has significant environmental issues, including thorium byproducts, tailings management, and the negative perception of cyanide and arsenic. China has already oversupplied the market, depressing prices in the near term. In

addition, large mining projects require large, upfront capital investment and will not come online for 7 to 10 years or more.

Canadian advantage

Canada has a large anchor company, significant related activity in startup and supplier companies, and a potentially exploitable natural resource.

Magna is headquartered in Ontario and primarily supplies GM, Ford, and Chrysler, in addition to Volkswagen, BMW, and Toyota. It reported total revenue of $26 billion in 2011 and operating income of $1.2 billion. It has a major manufacturing presence in Canada, employing 56,000 in manufacturing, assembly, and R&D (108,000 worldwide, including 73,000 in the United States). Currently, Magna manufactures cars for several OEMs around the world, including the Peugeot RCZ, Aston Martin Rapide, Mini Countryman, and Paceman. It is also an EV technology leader, supplying the EV drivetrain for Ford's Focus Electric.

Canada has robust startup activity in EV technologies, but these startups will face stiff competition with other major suppliers and major OEMs.

- Phostech Lithium – Li-ion cathodes
- Effenco – hybrid hydraulic system for trucks
- Delta-Q, Gan Systems, Accelerated Systems, Inc. – power electronics and drivetrain
- Nemo Vehicles, ZENN – low-speed EV
- TM4, Advanced Lithium, Bathium, Electrovaya – motors, batteries.

Canada has a large mining industry and abundant rare-earth deposits, including 500,000 tons of rare earths worth an estimated $296 billion (Alberta Black Shale Deposit). DNI Metals, in Toronto, has proposed to use bioleaching instead of cyanide/arsenic, and active exploration is being conducted in several other areas, with proposals for extraction in the 2015 to 2020 time frame.

Investment thesis

Canada's opportunity in the short term will be to maintain and expand its position as a global auto manufacturer and technology power and, in the long term, to seek

ways to increase its supplier advantage in auto components (such as electric motors and other technologies, like lightweighting).

TRANSPORTATION: ADVANCED TRAINS AND AIRCRAFT

Technology areas under consideration

Considered in this area are: train systems, including electric, rail, and urban transit hardware, controls and services, lightweight materials, and efficiency; and aircraft systems, including advanced airframe, engine design, and alternative aircraft fuels.

Market and technology overview

Worldwide train and aircraft markets are large and growing moderately, with some niche technology development. Within the train market, electric rolling stock will grow rapidly to $48 billion in 2020. The least fragmented segments are high-speed and urban passenger rail.

Within the aircraft market, 12,800 aircraft of all types are projected to be delivered through 2030, with most growth in the 60- to 99-seat segment. Manufacturers are improving fuel efficiency through advanced engine design and lightweighting.

The existing technology in both areas is relatively mature, but opportunities exist in specific areas, including:

- Electric train controls optimization and energy management
- Aircraft fuel efficiency, including engine technology and lightweighting
- Alternative, non-fossil-fuel-based sources of aircraft fuel to reduce exposure to market risk for fossil fuels.

Rail electrification is dependent on regulation and public funding, and disruptive fuel-efficient aircraft technologies are immature.

Canadian advantage

Canada has a major anchor company and several smaller aerospace companies. Bombardier Aerospace is the third largest global aircraft OEM after Airbus and

Boeing. Several other aerospace suppliers and OEMs are located in Canada, including:

- Pratt & Whitney and Rolls-Royce engine manufacturers have large manufacturing facilities in Canada.
- Bell Helicopter manufactures commercial rotocraft products in Mirabel, Québec.
- Hértoux-Devek is a specialist in landing gear design and manufacture.

Bombardier Transportation is the third largest global rail company ($10 billion in revenues in 2011), although 25,400 of its 34,900 employees are located in the European Union. It is a market leader in urban transit and has a strong position in all segments below high speed, but it is facing strong cost competition from China and Russia.

Investment thesis

Canada could maintain its major anchor companies by encouraging continued innovation and domestic manufacturing growth in these large industries. Bombardier Aerospace revenues were $8.6 billion in 2011, and it directly employs 20,000 people in Canada, with many more employed indirectly through suppliers and services. Pratt & Whitney Canada contributes $2 billion of GDP impact.

TRANSPORTATION: FUEL CELL SYSTEMS

Technology areas under consideration

The hydrogen fuel cell technologies considered in this report fall into three categories: 1) equipment and the associated technical expertise for automotive hydrogen fuel cells; 2) the technologies associated with refueling infrastructure; and 3) fuel cells in grid energy storage.

Market and technology overview

The hydrogen fuel cell market, both in vehicles and stationary systems (i.e., for use in distributed power and grid storage), has large long-term potential, but it is dependent on overcoming both technical and infrastructure barriers.

Hydrogen fuel cells are attractive to many automotive OEMs as a long-term solution for reducing vehicle emissions and increasing fuel efficiency while using similar drivetrain components (e.g., electric motors and power converters) as in electric vehicles.

Fuel cell vehicle (FCV) economic viability is highly dependent on carbon price. The McKinsey Automotive Practice calculates that under a stringent regulation of 10 g CO_2 per km, FCVs would capture approximately 3 percent market share by 2020 and 30 percent market share by 2030. However, the study also shows that in a less stringent regulatory environment of 95 g CO_2 per km, FCVs would capture no market share in 2020 and less than 2 percent by 2030.

Fuel cell refueling infrastructure will require an estimated $3 billion in global investment for each 1 million fuel cell electric vehicles in 2020. Some governments have made commitments to fuel cell infrastructure (e.g., Japan's Hydrogen Fuel Cell Demonstration Project and, more recently, the German National Innovation Programme for Hydrogen and Fuel Cell Technology).

Electric vehicles, one of the main competitors for fuel cell technology, are on a cost curve driven by incremental advances in battery technology (materials, packaging, management) that put electric vehicles (PHEV and BEV) on a path to mass adoption after 2030. Much of the technology originated with the development of Li-ion batteries for consumer use. Fuel cells for vehicles are on a different technology path. Current applications are in niches where power, refueling, cost, and vibration requirements are less strict than in automotive applications. It is unclear whether fuel cells will find significant application first in large-scale storage applications and then in automotive applications or vice versa.

In larger vehicles and fleets – including long- and short-haul trucks, forklifts, and other industrial vehicles – fuel cells compete with CNG/LNG in regions where natural gas is expensive and possibly with biofuels as renewable fuels. Because of their zero emissions (except for water vapour), fuel cells can be used in indoor or other closed environments.

The market for grid storage applications has been projected to grow in the next 10 years to $24 billion (Pike Research, 2011). Fuel cells compete with batteries for storage applications but have different characteristics. While they are not as energy efficient, they can be used to convert electricity into hydrogen gas or vice versa and so can be integrated into many different industrial and storage

processes. Direct methanol fuel cells (DMFCs) are smaller than HFCs and more suitable for portable applications like powering laptops and cellphones.

Canadian advantage

Canada has made a significant investment in fuel cell research and manufacturing and has developed technological expertise. Ballard Power Systems in Vancouver, British Columbia, is a fuel cell pioneer that launched the fuel cell hub in Vancouver. However, it has recently divested itself of FCVs to focus on niche areas such as forklifts and stationary power. Nevertheless, major FCV research continues at the Automotive Fuel Cell Cooperation and other Canadian centres like Hydrogenics in Toronto, Ontario.

Investment thesis

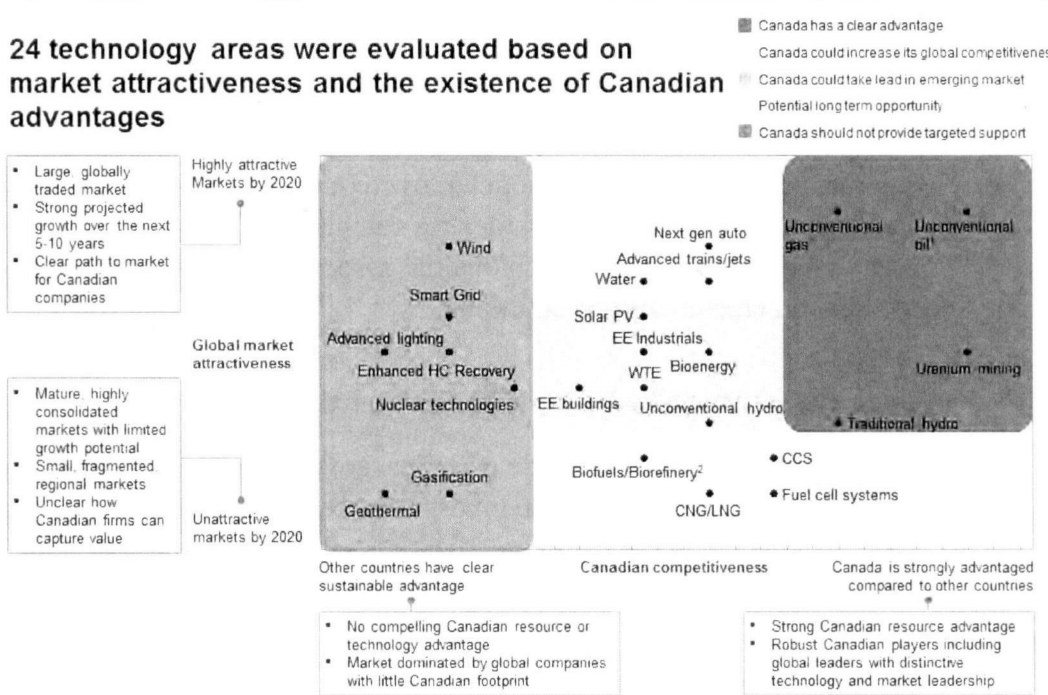
Canada's past investments in fuel cell technology has attracted manufacturers and formed a strong research hub in fuel cell development. Because of the early stage of fuel cell technology, Canada's opportunity is to continue to support R&D and early commercialization of fuel cells in automotive and grid application, including both product development and fuel cell infrastructure.

Section C

MARKET ATTRACTIVENESS VERSUS CANADIAN COMPETITIVENESS

As shown in Exhibit 9, we plotted the technology areas on a grid using measures of global market attractiveness and Canadian competitiveness. The analysis revealed for the next 10 to 20 years, both the most promising activities from a market standpoint and the activities where Canada has a substantial advantage. The implication is that Canada will benefit most from technologies where it: 1) has a clear advantage compared to other countries; 2) is in a position to increase its competitiveness; or 3) could take the lead in an emerging market.

EXHIBIT 9



1 Global capex and sales from Canadian oil or gas only
2 Global capex and sales from cellulosic biofuels only (includes agriculture waste)

SOURCE: McKinsey Global Energy Perspective Model, market research, expert interviews

OVERCOMING THE KEY CHALLENGES: MARKET FORCES VERSUS GOVERNMENT ACTION

Once the technologies and their market characteristics were identified, as described in Sections A and B, we sought to define, for each technology, the barriers to commercialization and then identify those barriers the government is uniquely positioned to resolve. That is, market forces will work effectively to erode certain barriers whereas, for certain other barriers, resolution can be significantly accelerated by government action.

Where market forces work best

Market forces work well to remove barriers wherever private companies, such as VC funds or large companies, are investing across the commercialization value chain to develop products and reduce costs by advancing along the learning curve. This includes existing companies, like energy companies, that are willing to invest in infrastructure (pipelines, gas stations) to sell more of their product. Private companies are also effective at removing demand barriers (e.g., renting equipment as a new business model to overcome high initial costs), and, sometimes, market structural challenges can be overcome through existing market mechanisms, like when industrial associations bring disparate companies together and create win-win solutions.

When government action is needed and why

When market forces fail to erode a barrier, government is uniquely positioned to act in two ways. It can stimulate investment, carrying companies through the "valleys of death" in the commercialization value chain, and it can stimulate demand by altering market conditions.

Stimulating investment

Where the financial risk profile of an investment exceeds private sector limitations, government access to lower interest rates can make all the difference. Sometimes, early applications of leading technologies involve high technical risk which can discourage private investors and result in worthy technologies perishing in the laboratory. Sometimes, the time to market for a technology may be too lengthy to attract industry funding for demonstrations and pilots. And

other times, the high capital costs of moving technologies through developmental learning curves may discourage industries from investing.

Stimulating demand

Government action may also be needed to create new market conditions to stimulate demand. Demand for economically attractive technologies may be lacking because consumers' perceptions are not well-addressed through market mechanisms. Structural barriers resulting from multi-party complexities can also stifle demand. For example, in building efficiency, renters benefit from energy efficiency (EE) in heating ventilation and air conditioning (HVAC), but owners pay for the HVAC unit, or, in waste-to energy, a new plant with better technology may be unable to access a waste stream because the waste utilities have no incentive to change. As well, development often stalls because of a "chicken and egg" issue where consumers will not adopt a technology without existing infrastructure and companies will not invest in infrastructure without customers to use it (as in electric vehicles).

ASSESSMENT OF MARKET BARRIERS AND POTENTIAL GOVERNMENT ACTIONS

For all 17 technologies in the four categories favourable for Canada (i.e., except category 5 where other countries have a sustainable advantage), we identified specific barriers along the value chain that fall into four groups: product barriers – the technology is currently immature and too unreliable for market; cost barriers – the technology is too expensive for adoption and needs further research, scale-up, or learning to make it economically viable; demand barriers – the technology may be cost-effective, but there is no demand for it for various reasons (e.g., negative public perception); and market structure barriers – there is demand for the technology and it is cost-effective, but a failure in the market is preventing the product from reaching customers. We assessed both when and how government could act to remove each barrier. In most mature technology areas (specifically, uranium mining, advanced trains and jets, and conventional hydroelectric generation), market forces are already eroding barriers. Even in some value chain areas of the emerging technologies, VC and large existing industry companies are aggressively investing to reduce the cost of technologies (e.g., shale gas drilling and fracking, bioenergy collection and processing,

municipal water treatment, many next-generation transportation components, and solar PV).

The rest of this section details our assessment, which ultimately identified five clusters of technologies where Canadian government action could make a difference, and offers example government actions to support these clusters:

- **Sustain Canadian advantage in unconventional oil and gas.** This cluster creates value primarily by enabling the export of domestic oil and gas resources and secondarily by exporting the environmental technologies globally to mining and fossil fuel extraction markets (water treatment, emissions, land remediation). Federal and provincial governments could set stricter staged regulations to spur innovation in environmental technologies and facilitate the transfer of environmental technologies to new markets (e.g., mining). This would have the added benefit of increasing the social licence to operate and thus enabling export to a wider range of jurisdictions. Canadian governments could also continue to support pilots for new technologies that could lower drilling or extraction costs for the oil sands, especially more efficient in situ oil sands technologies (e.g., fostering collaboration between different industry companies, offering government prizes for technology challenges related to lowering extraction costs).
- **Cultivate Canadian leadership in next-generation transportation.** This cluster creates value primarily through the export of EV and PHEV automotive components to the global market and secondarily through domestic fuel-efficiency gains from the adoption of these technologies. Canada could capture domestic fuel efficiency gains and attract foreign investment by accelerating the adoption of electric/hybrid automobiles and natural gas heavy fleets. At least two courses of action are open: continue to fund public-private infrastructure investment partnerships or create more stringent fuel efficiency regulations than the United States. While the impact potential is high in both cases, the governments could decide on the approach based on the political environment and availability of funds. To build on Canada's existing auto supply advantage, federal and provincial governments could also foster collaboration between rare-earth mining companies, auto suppliers, and OEMs to develop e-motor hubs in Canada.
- **Cultivate Canadian leadership in the energy efficiency cluster.** This creates value primarily by increasing the global competitiveness of energy-intensive Canadian industrial companies, secondarily by exporting energy-efficient buildings, industrials, or water technologies and services as they are

- **Invest selectively among distributed power generation technologies (unconventional hydro, biomass combined heat and power (CHP), waste to energy, solar off-grid) based on risks/rewards.** Distributed power generation is an attractive emerging global market where Canada could commercialize technologies domestically with subsequent value creation through export. While each technology is slightly different, most of them could benefit from government assistance in either co-funding or fostering collaboration in pilots (e.g., securing a waste source for a waste-to-energy demo plant). In all cases, the export market offers high potential returns but also strong competition from foreign companies. The largest risk is in foreign companies acquiring Canadian technology before manufacturing and supply chains are established in Canada, reducing economic and job impact in Canada.
- **Monitor and invest carefully in long-term opportunities.** Carbon capture and storage (CCS), hydrogen fuel systems, and biofuels/biorefinery all have questionable market size and timing, driven by either regulatory or technology uncertainty. Given its limited funds, the Canadian government would benefit from monitoring key indicators of market development before investing (e.g., an approximately $40 carbon price mandated in major markets for CCS, major industry investment in fuel cell infrastructure and vehicles, mandate for bioproducts in major markets).

What follows are individual assessments of the current government activity, the barriers to success, and whether further government action would help to overcome these barriers for each priority technology. If further government

FOSSIL FUELS: UNCONVENTIONAL OIL

Canada's provincial and federal government activity today

Government activity in the unconventional oil industry focuses on R&D support and regulations. Both federal and provincial governments fund R&D, either directly or through programs such as Sustainable Development Technology Canada (SDTC) and Alberta Innovates. Governments also collaborate with industry groups, universities, and one another.

Environmental regulations come from both federal and provincial governments. At the federal level, the National Energy Board regulates the oil industry's operations, and aspects of the oil operations are subject to Federal Base Level Industrial Emissions Requirements (BLIERs), managed by Environment Canada. Some provincial governments regulate as well. Alberta has greenhouse gas (GHG) intensity limits, with a compliance mechanism that allows companies to pay into a clean energy fund rather than meet the emission targets. The federal government is discussing GHG limits with similar flexible compliance mechanisms.

Barriers to innovation and potential government actions

The Canadian oil sands industry's competitiveness depends on lowering the cost of drilling and extraction, upgrading bitumen, managing water and tailings, exporting bitumen through the pipelines and, perhaps most important, maintaining the social licence to operate. Each of these areas faces technological and socio-political barriers. The government is involved in oil sands development and regulation today, but opportunities exist to improve environmental standards for water and tailings management, which would make Canadian companies in these areas competitive worldwide.

Drilling and extraction of bitumen from oil sands

Product barrier. To remain competitive as reserves are depleted or if the oil price decreases, continuing development of drilling and extraction techniques is required.

Although the major oil companies spend large amounts on R&D, the viability of a new extraction technique should be demonstrated at scale in a working oil field. Despite the fact that the new extraction technique will lower cost in the long run, operators must spend capital and forego production in the short term. Delaying spending on technology improvement leaves the industry vulnerable to falling oil prices and the possibility of a simultaneous downturn in the global oil market when reserves are dwindling and capital expenditures for new technologies are needed most.

The government's actions are currently sufficient. The government and the industry are aware of these risks and are addressing them directly. The oil majors view continued improvement of drilling technology as a core strength they must actively maintain and are investing heavily in R&D. The industry and government have successfully collaborated before to produce the existing oil sands drilling technologies and continue to have close relationships.

Bitumen upgrading and refining

Market structure barrier. Currently, Canadian companies are shipping raw bitumen to US refineries because of capacity constraints in Canadian refineries and excess capacity in the United States. It enters US markets at a discount because of oversupply in the US market and low natural gas prices. Canadian companies are willing to accept the discount because of the high capital costs, exposure to oil price risk, and social resistance (resulting from high refinery GHG emissions) associated with building new refining and upgrading capacity in Canada.

Limited government action is required. Oil companies are investing moderately in refinery R&D, adequate capital is available for large projects, and the industry has shown willingness to invest when required. The oil upgrading market has demonstrated flexibility and long-term thinking in adapting to new product flows (e.g., willingness to propose and build large pipelines to fill overcapacity), and upgrading is allocated across the industry in an operating market.

Water, land, air, and tailings management

Product barrier. Water and environmental management are major costs for oil sands operations and crucial to maintaining the social licence to operate. As in drilling and extraction, the technology bottleneck for new water and tailings

management products is demonstration at scale in a working field, which has the same tradeoff between production and technology development.

Additional government action could be considered. Water and environmental management are usually not considered as central to a company's advantage as drilling and extraction techniques. Although industry associations have been formed (e.g., COSIA) to develop new techniques, the incentives for reducing water consumption and usage are indirect. Because water is expected to become scarcer and more costly over the long term, an appropriate government role would be to anticipate these trends and create a Canadian advantage by introducing stricter water regulation, thereby encouraging water-efficient technologies by Canadian companies to progress ahead of other industries. This would both increase the industry's cost-competitiveness in the long term and help ensure its social licence to operate.

Pipelines and pipeline safety

Demand barrier. The regions that could benefit economically from pipeline traffic through partial ownership or fees are actively blocking pipeline construction, including regions in both British Columbia and the United States. Existing pipelines to the West Coast are at capacity or oversubscribed, and the volume of oil is expected to double in the next 20 years. At stake is the value of long-term access to Asian and West Coast markets where Canadian bitumen is at a premium compared to the current path via US oil refineries.

Much of the objection to pipelines arises from aversion to the environmental risk posed by pipeline spills of bitumen, which are more damaging than equivalent diesel spills. Up for debate is whether it is possible to compensate adequately for large-scale environmental risks and damage, and how to go about it.

The government's actions are currently sufficient. The government is actively supporting R&D in pipeline safety and testing, continuing education around environmental risks and hazards, as well as safety improvements, and creating the necessary frameworks to create social licence to operate. Policy issues are debated openly and publicly at provincial and national levels.

FOSSIL FUELS: UNCONVENTIONAL GAS

Canada's provincial and federal government activity today

Government involvement in shale gas takes a variety of forms. Federal BLIERs apply to some processes, and the recent Responsible Resource Development plan streamlines the federal review of major projects to reduce regulatory burden. Most regulatory jurisdiction belongs to the provinces and some are adapting conventional gas regulations to shale gas.

Other government efforts involve education and fostering collaboration; for example, the federal government publishes Shale Gas Fact Sheets and participates in knowledge sharing with provincial governments.

Barriers to innovation and possible government actions

The Canadian unconventional gas industry faces strong cost pressure from US shale gas sources and a transportation cost disadvantage in US markets. To compete, Canadian companies should continue to innovate to lower the cost of drilling and hydraulic fracturing (fracking), develop technologies to efficiently monitor gas fields, manage water and tailings, and find new paths to market.

Drilling and fracking technology

Cost barrier. Drilling and fracking are 50 to 60 percent of the cost of natural gas extraction. Small, regional Canadian companies have developed expertise in particular geologies and fields and are also pioneering alternative extraction techniques. Although large oil field services and equipment (OFSE) companies also offer drilling and fracking services and capture a large part of the market, they are not as advanced as the smaller companies because of the risk of out-innovating their own operations.

Economies of scale and reliability, both valued by oil companies, improve as companies grow to more than 50 rigs in size. Faced with a choice of using a number of small drilling and fracking companies or a larger but less efficient OFSE, many global gas companies have chosen a middle ground – investing in smaller companies and growing them to regional scale and, in some cases, learning from and transferring the expertise to different global regions.

Limited government action is required. The market has demonstrated that private operators are willing to invest in innovation and the growth of Canadian companies. Since most innovations are directly tied to reducing the cost and improving the efficiency of extraction, private gas operators have strong incentives to identify and grow innovative technologies.

Monitoring and maintaining gas fields

Product barrier. As wells in newer gas fields are smaller and more numerous, they require advanced monitoring and control technologies. These technologies directly improve the productivity of a gas field by optimizing yield from individual wells, and lower the cost of well-monitoring and control.

Limited government action is required. Improvements in well-monitoring, productivity and control all improve the performance of gas fields and provide a strong incentive for companies to pursue research, development, and innovation. Incremental innovation is possible because new technologies can be tested on existing or new gas fields without requiring serious capital investment or risk tradeoffs.

Water treatment and management

Product barrier. As in oil extraction, water management is critical to controlling drilling, fracturing, and extraction costs. Although water-recycling technologies exist at small scales, the technology can only be proven at full scale, necessitating the same tradeoffs between long-term benefit and short-term capital cost and operational risk.

Additional government action could be considered. Like the oil sands, continuing global pressure on water resources will cause water management to become increasingly important to both managing costs and maintaining social licence to operate. Unfortunately, the industry is only marginally aware of this trend. By spurring industry innovation through regulations that anticipate regulatory trends elsewhere (e.g., in the United States, where many water regulation frameworks are under development), the Canadian government can both increase long-term Canadian competitiveness in markets with strict water regulations and ensure the social licence to operate.

LNG/GTL export

Market structure barrier. To avoid the inherent discount in exporting to the US natural gas market, traditional liquefied natural gas (LNG) and gas-to-liquid (GTL) technologies can be used to transport gas to distant markets or convert it to a higher-value product. The infrastructure for these technologies is highly capital intensive and is employed mostly on large gas fields without other transportation opportunities. Companies are also beginning to develop small-scale mobile GTL technologies that are useful in smaller gas fields.

Limited government action is required. The technology for large-scale LNG and GTL is well known and is being developed for other markets around the world. Multinationals have made significant investments in this technology, which suggests the industry is responsive to economic signals for investment (e.g., large oil/gas differentials or supply/demand imbalances) and is willing to take risks in LNG/GTL investments.

FOSSIL FUELS: CARBON CAPTURE AND STORAGE

Canada's provincial and federal government activity today

Canadian governments have used a variety of levers to support carbon capture and storage (CCS). Federal and provincial funding has gone to demonstration projects and a backbone CO_2 pipeline. Alberta offers double credit value for captured CO_2, and Environment Canada has proposed CO_2 limits that would force coal-fired plants to install CCS. Many provinces are updating safety regulations for pipelines, exploration, and injection. Additionally, Alberta produces educational material, and some provinces require public outreach for projects.

Barriers to innovation and potential government actions

CCS will likely be an integral part of the carbon economy that will emerge over the next 40 years. CCS technology innovation faces two barriers: 1) the current cost of CCS technology is prohibitively expensive for stand-alone CO_2 emission control, especially without an established, high carbon price; and 2) the regulatory and legal framework for carbon sequestration is not yet established, which raises a barrier to commercial entry.

Capture of CO_2 from integrated and retrofit industrial sources

Product barrier. CCS remains prohibitively expensive for stand-alone CO_2 emissions control, primarily those not coupled to another process that uses large volumes of CO_2. Pilot projects, like the Weyburn-Midale Carbon Dioxide project, have demonstrated the technical feasibility of CCS for enhanced oil recovery (EOR), but the cost to capture the CO_2 is still higher than from other sources. Advances in technology and carbon regulations (i.e., carbon prices of $50 per tonne) that are necessary to make CSS economical on a large scale are not expected before 2030.

Additional government action could be considered, as the long time frame for technical innovation, the large scale of pilots needed to demonstrate the technology, and the uncertain regulatory future will slow industry investment in CCS.

Given the importance of CCS to the Canadian social licence to operate in oil sands and coal, the potential short- and long-term gains of developing an economically viable CCS technology, and the government's current level of investment in CCS research, if investment from industry is inadequate, the government may consider increasing its investment in the research and development of CCS technologies. Basic research could be supported in a number of ways, including university funding, industrial collaborations, or open-market contest funding (e.g., the US government L-prize for LED cost reductions). Advances in basic research may be applicable to a broad range of industrial processes outside power-plant retrofit and large-scale sequestration.

To mitigate the costs of research and long-term risks, further non-basic science funding could concentrate on the near-term economic applications of CCS. These will mostly be in EOR, which requires large volumes of CO_2 and generates significant immediate economic value. It may also be possible to develop or modify other industrial processes to use and store CO_2 (like efforts to capture CO_2 in building cement). The risk of this approach is that CCS-EOR may be technically feasible and economically attractive only under a narrow set of conditions (oil or gas geology are both well-suited to EOR and long-term CO_2 sequestration, co-location of a large CO_2 source, and aligned commercial time frames). Before further investment, the Canadian government may want to wait for appropriate market signals that indicate a shift to low-carbon power production. This may occur via international or industry commitments to CCS.

CO_2 sequestration and measurement, monitoring, and verification (MMV) technology

Product barrier. The long-term sequestration of CO_2 in geological sites faces both technical and regulatory hurdles. To test whether large-scale CCS will cause seismic disturbances or leak CO_2 in the long term, it is necessary to build large-scale sequestration pilots in aquifers and underground caverns. Industrial investment is limited by the immaturity of the regulatory and legal framework surrounding carbon sequestration. For instance, it is unclear: if the Canadian government or private industry will accept long-term liability for CO_2 leakage or environmental damage; what the procedures are for site characterization, approval, and monitoring; and what conditions must be met before the carbon is considered sequestered for accounting purposes.

The government's actions are currently sufficient. Investment in sequestration pilots and technology is probably sufficient for the 2020 time frame since present applications of CCS will likely focus on EOR, where the technology is more mature. For longer time frames, further government actions could be required to scale up with demand and to regulate the long-term risks.

RENEWABLE AND CLEAN ENERGY: SOLAR PV

Canada's provincial and federal government activity today

Most federal and provincial activity is in investment and subsidies. The federal government has been supporting solar development, but it scaled back funding for solar projects last year. Ontario has a feed in tariff (FIT) program that has attracted significant investment, but today's lower rates are decreasing demand for solar in Ontario. Quebec recently launched a program to partially cover installation costs for off-grid solar PV, primarily in commercial or industrial applications. Similarly, to reduce fuel use, the Northwest Territories Alternative Energy Technologies Program offers funding for up to one-third of installation costs.

Barriers, government actions impact and risk

The solar PV industry is in the middle of a cost shakedown affecting all parts of the solar PV value chain. Most upstream positions (e.g., polysilicon production, module manufacturing and packaging) are consolidating and commoditizing.

However, significant opportunity remains for Canada to develop and export off-grid integrated products (e.g., combined solar-diesel-battery systems) to developing countries and other markets where off-grid solar will be the major source of power. In these applications, system integration, engineering, and design expertise remain important in delivering highly reliable, low-cost, and low- maintenance products.

Canada also has a domestic opportunity to rapidly adopt PV in off-grid and peak applications where it is economically feasible. By accelerating adoption, Canada can both decrease the cost of supplying power to these markets and gain expertise in the manufacture of off-grid technologies.

Solar PV off-grid applications development

Cost barrier. The integration of photovoltaic, battery, and diesel generation technologies into a stand-alone off-grid power module faces several technical and business hurdles. Because it functions as an electric utility for several hundreds or thousands of people, it must be at least as reliable as a comparable diesel-only power generator. It must be zero-service (which is very difficult to achieve), be serviceable by local service technicians, or have as part of its value proposition a trained service network.

Additional government action could be considered to help overcome some of these cost hurdles. The major bottleneck in commercial development will be establishing field reliability, acquiring experience, and building a service model. The first companies to complete commercial-scale pilots will have significant advantages in marketing, design, and export. The Canadian government is in a position to accelerate commercialization by funding early-stage research and providing incentives for early adoption and testing by remote communities in Canada.

Adoption for off-grid residential/industrial operations and communities

Market structure barrier. In addition to the technical barriers mentioned above, the domestic Canadian market has several notable barriers to the adoption of off-grid integrated solar/diesel/battery technologies. For example, utilities, like HydroOne Remote Communities, that have invested in diesel-based power generation and have received subsidies for providing electricity to remote communities, may not be willing to accept the risk and capital expense of

switching to an integrated system, even though it may be more cost-effective in the long run. Such risk aversion and strong commitment to capital already invested, versus the total cost of ownership, is typical of small communities and utilities.

Additional government action could be considered to overcome some of these market failures. The government may be able to revise existing subsidy programs so they encourage adoption of innovative technologies and create both a domestic market for new technologies and long-term cost savings.

RENEWABLE AND CLEAN ENERGY: BIOENERGY

Canada's provincial and federal government activity today

Canadian governments use several levers to support the biopower/bioheat industry. The federal government has invested in some R&D and offers accelerated tax depreciation of capital expenditures. The BC Bioenergy Strategy supports the development of industry through R&D investment, standards, education, and the coordination of stakeholders. Additionally, some provinces have renewable portfolio standards that accept biomass electricity as a renewable and provincial regulations that govern harvesting to encourage sustainability in the industry.

The federal government uses softer collaborative approaches to support the industry. Several of its programs foster collaboration and encourage knowledge transfer. The federal government has also worked with universities to implement Combined Heat and Power (CHP) technology pilots.

Barriers to innovation and potential government actions

The McKinsey GEP model forecasts that in 2020 the EU will spend $100 billion to $200 billion in capex on major biopower projects that address a shift away from fossil and nuclear power sources. However, this capital expenditure may not come to fruition as doubts about the global supply of biopower pellet feedstock (both from forestry and agricultural residues and whole tree harvesting) are currently being explored. Canada can enter this market if it develops efficient small-scale CHP and on-demand distributed power technologies. The extensive shift to biopower will also necessitate the import or domestic harvest of large amounts of biomass feedstock. Canada can serve this market if it lowers the cost

of collecting, processing, and shipping feedstock to the European Union, and makes itself competitive with the United States, Sweden, and Russia, as well as domestic EU biomass sources.

Collection and processing of biomass for biopower/bioheat

Cost barrier. To convert woody waste biomass (e.g., sawdust and waste pulp) into a pelletized fuel that can be transported and used in large-scale power generation, it must be collected, processed, dried, and densified. The process is labour- and energy-intensive and is a significant component of the cost of bioenergy or bioheat production. The overall cost of the biopower supply chain is higher than coal or natural gas and will only be competitive if the demand for renewable energy (i.e., driven by quotas in the European Union) increases the price of biomass significantly.

Limited government action is required, as Canadian companies have identified the European Union as a likely target market. They are already shipping wood pellets there to meet EU demand for Canadian feedstock and have demonstrated willingness to continue research into lowering the cost of feedstock without additional support from subsidies or regulations.

Technology development for biomass combined heat and power (CHP)

Product barrier. Canada's natural forest resources and experience with CHP in the pulp and paper industry create a strong Canadian advantage in CHP technologies, which has led to the emergence of small, quickly growing Canadian companies. However, given the low cost of hydropower, domestic adoption of small CHP systems has been limited to niche areas, like the pulp and paper industry, which is an existing source of waste-derived feedstock.

High-efficiency and low-cost CHP technologies have been piloted on a small scale, but they need further investment and commercial-scale development to become commercially viable. This includes testing the plant's commercial operation – verifying its compliance with air regulations, its ability to use a variety of biomass feedstocks, and its reliability – as well as demonstrating competitive capex and operational costs.

Additional government action could be considered for small-scale biomass CHP because of the inherent disincentive caused by inexpensive hydropower.

To encourage commercialization, the federal government could introduce cost-sharing programs between federal, provincial, and municipal governments to bridge growth to the commercialization phase. Building 5 to 10 plants using this program would help prove the technologies to international buyers and bring the technologies down the cost curve, keeping Canadian companies competitive in the global market.

The biomass CHP market is also dependent on the regulatory policies of the United States and the European Union. Without regulations for renewable mandates, a shift toward low-cost natural gas CHP would severely decrease the market for higher-cost biomass-based CHP systems.

To counter large multinationals' tendency to acquire small companies and move them outside Canada, the federal government could also introduce a long-term (e.g., 15-year) repayment period on funds received from the government, contingent on the company remaining in Canada (i.e., if the company left the country, the funds would have to be repaid within a shorter period) and achieving profitability (i.e., repayment would be required only if the company was successful), and offer tax breaks on export sales (as a further incentive and reward for rapid growth and export). The risk of this approach is that, if the conditions are too binding, small companies would be reluctant to accept federal funds that would eliminate their option of leaving Canada to grow. If done correctly, however, such a program could create a win-win environment for the government (creating long-term domestic GDP and job growth) and small CHP companies (providing a short-term cash injection and long-term profitability).

A long-term risk is that cost pressures will increase as the CHP market evolves, CHP technology becomes more mainstream, and purchasers look for low-cost units, possibly built in China. By establishing a large-scale CHP supply chain and manufacturing industry, Canada could stay ahead of cost pressures and gain scale advantages before other competitors.

RENEWABLE AND CLEAN ENERGY: BIOFUELS/BIOREFINERY

Canada's provincial and federal government activity today

The biofuels/biorefinery sector receives significant government funding through a number of programs. Federal programs provide capital and operating incentives to biofuels production facilities; these programs include the ecoAgriculture

Biofuels Capital Initiative, the ecoENERGY for Biofuels Program, and the Ethanol Expansion Program. Risk capital is provided by SDTC through the NextGen Biofuels Fund and the SD Tech Fund. First-generation biofuels researchers have received heavy R&D investment, but second-generation biofuels researchers have received less because of a large increase in research interest and relatively steady amounts of total available funding. FPInnovations created to coordinate Canada's research efforts, was formed as a merger of several research institutes, including NRCan's Wood Fibre Centre. The federal government has also invested in the integration of biorefinery units into CHP gasification units through the iFIT program, which is supported by CanmetENERGY. Provincial funding contributes to seven bioethanol programs and six biodiesel programs.

Beyond funding, governments use regulations and standards to support the biofuels/biorefinery industry. Federal Renewable Fuel Regulations mandate a minimum 5 percent renewable content in gasoline and 2 percent renewable content in diesel and fuel oil. Low-carbon fuel standards in British Columbia and Ontario also encourage the adoption of biofuels.

Barriers to innovation and potential government actions

The market for next-generation biofuels is driven by the RFS2 (renewable fuel standard 2.0) regulation in the United States and biofuels directives in the European Union. Canada has opportunities to 1) export lignocellulosic (LC) feedstock to the United States; 2) develop lignocellulosic processing technologies and export second-generation biofuels to the United States and the European Union; and 3) develop biorefinery technology over the long term for export of high-value bioproducts globally.

The growth and collection of LC (forest, agricultural, bio-waste) feedstock

Cost barrier. The major barrier for increased Canadian competitiveness is the cost of sourcing LC feedstock, which contributes 50 to 60 percent to the total cost of this biofuel. Prices for feedstock also vary sharply from region to region, and there are few guarantees of long-term feedstock pricing.

The government's actions are currently sufficient. Canadian forestry companies can already provide feedstock at a competitive cost because of their experience in managing forest and agricultural residues (e.g., they already have the technologies and infrastructure for efficiently gathering residues from forest

floors and recovering residues in pulp and paper processing). The government also has created tools and programs to encourage the availability of feedstock for commercial projects. Canada has a further advantage in its provincial system of forest management. Unlike private owners in the United States, the Canadian government is able to encourage long-term investment by entering into long-term feedstock supply contracts with stable prices.

Generation of LC biofuel (feedstock processing and chemistry)

Product barrier. The major barrier is that LC biofuels with woody biomass have not yet reached cost competitiveness with agricultural-based LC biofuels. To develop large-scale, commercially viable operations and to reduce costs, it will be necessary to advance engineering expertise and build a solid manufacturing and supply infrastructure. Although small pilots in the United States and Canada have been successful, companies attempting to reach commercial scale face technology development risks, difficulties in securing long-term supplies of feedstock at reasonable prices, and the risk that subsidies for biofuels may be revoked.

The government's actions are currently sufficient. Federal funding for commercial-stage biofuels development is adequate to continue driving Canadian commercialization and competitiveness. The industry is pursuing biofuel process R&D (e.g., fermentation, catalysts), and publicly funded university research into LC chemistry is actively underway.

Adoption and science of the biorefinery concept

Product barrier. The major barrier to biorefinery commercialization and adoption in Canada is that further R&D at both the chemical and the pilot levels is necessary. While chemical or enzyme-based LC processing can yield value-added petroleum substitutes (e.g., butanol and polypropylene) as renewable commodity chemicals, there is no consensus on the way to achieve this. Economics and scaling research is needed to prove this technology in the pilot phase. The short-term value may be in integrating the biorefinery concept with existing industrial processes (like extracting high-value chemicals before inputting materials into the pulp and paper value chain), and the long-term value may be greatest in creating precursors for new biomass-based products. This includes the existing iFIT program, which has retro-fitted gasification units to

existing forestry product mills. These units would provide both CHP and possibly a higher-value stream of syngas for bioproduct production.

Additional government action could be considered to ensure that Canada gains a competitive advantage. The demand for biorefinery products is high, and Canada has a natural advantage in its extensive feedstock supply (e.g., agricultural and forestry residues). However, without the development of a domestic biorefinery industry, Canada will only be able to export low-value biomass.

Long-term funding of R&D for biorefinery value-added products could give Canada a leading role and first-mover advantage in the biorefinery market. It is unclear, however, whether woody biomass, which is one of Canada's main sources, will be as cost-effective as other feedstocks, such as agricultural waste and genetically engineered plants, or whether Canada will have a unique advantage over US and EU efforts.

A second alternative is to wait for technologies to develop in the United States and the European Union. Once this happens, likely in the 2030 time frame, Canada could adopt the technologies for use with its large feedstock resources. The R&D dollars that Canada would save could be put to use elsewhere. However, it is also possible that technology might never be developed for woody biomass, leaving Canada as a low-value biomass exporter. With any action, there is risk involved in committing to biorefinery technology, and Canada may want to wait until significant and long-term commitments are made that will drive sustainable demand for biorefinery products.

RENEWABLE AND CLEAN ENERGY: UNCONVENTIONAL HYDRO/MARINE POWER

Canada's provincial and federal government activity today

A number of government actions are underway in the unconventional hydro/marine power sector. The federal government is funding R&D of small unconventional hydro through universities, SDTC, and others, and it is also creating cross-cutting standards and regulations.

Nova Scotia has also been involved in marine energy. The Fundy Ocean Research Centre for Energy manages research programs in ocean-monitoring

systems and cables, and a Nova Scotia Community FIT program includes subsidies for marine power.

Barriers to innovation and potential government actions

Unconventional hydro and marine power are areas where the global opportunity is large, but both demand and technological barriers exist. Commercial run-of-river hydropower plants have been built, but domestic demand for the technology is low because of existing low hydropower costs and the remoteness of viable locations. Hydrokinetic turbines are a potentially disruptive technology that can capture the hydropower in rivers and streams. Marine and tidal power are also nascent technologies with potentially large markets.

Run-of-river hydroelectric projects

Demand barrier. The development of Canadian run-of-river technology is limited by low demand. Because the river is not blocked to create high water pressures, run-of-river projects generally have lower power than conventional hydro, can be capital-intensive (some projects achieve higher pressures by constructing long concrete feeder tunnels) and are only cost-effective where the river drops steeply. Like many hydro projects, ideal locations also tend to be far from population centres, incurring high costs for power transmission and distribution.

The government's actions are currently sufficient, as its investment in domestic adoption of run-of-river technology through FIT and public-private partnership (PPP) mechanisms have increased development and commercial investment where practical.

Hydrokinetic turbine and generator technologies

Product barrier. The generation of power from low-head hydrokinetic turbines is at an early phase of testing. Small startup companies are piloting prototypes for long-term reliability and continuing their engineering efforts to reduce installation and maintenance costs.

Additional government action could be considered. To date, government activity has identified small companies in hydrokinetic power and facilitated pilot scale-up and growth. Hydrokinetic power is a potentially fast-growing market with low risk and high profitability. Until Canada's startup companies grow to

sufficient size, they risk being acquired by large companies that may choose to move operations to low-cost manufacturing countries. The government could push against this in two ways:

- First, the government could create conditions whereby Canadian companies can grow quickly to commercial scale and create a large manufacturing and supply base that makes it advantageous for an acquiring company to operate in Canada. The technology would have an early-mover advantage over technologies developed in the United States and the European Union, where little unconventional hydro technology development is being pursued today.
- Second, the government could foster collaboration between unconventional and conventional hydropower companies to encourage knowledge transfer around cost reduction, negotiation, selling to utilities, and creating joint ventures between public investment and power utilities.

Marine power technologies (tidal, wave)

Product barrier. The generation of power from marine energy (tidal, wave) still requires further R&D and pilot testing before commercialization. Canadian expertise in tidal energy has promise but still requires large cost reductions for economic viability.

The government's actions are currently sufficient. The government has already identified opportunities in marine power and facilitated pilot-scale activity. Government mechanisms to identify disruptive technologies will probably lead to new technologies that have commercial viability. Pilot activity to test new disruptive technologies will likely start beyond the 2020 time frame. If and when this occurs, further government activity could be warranted.

BUILDINGS AND COMMUNITIES: ENERGY-EFFICIENT BUILDINGS

Canada's provincial and federal government activity today

Government action in energy-efficient buildings varies. The federal government performs most of Canada's R&D in this area because few companies have the required research capacity. The National Energy Code 2015 is stringent but voluntary for provinces and several have opted for more lenient codes. Some provinces are directly financing EE buildings or experimenting with innovative financing.

Governments are involved as well in education and knowledge exchange. Both federal and provincial governments invest in extensive education efforts targeted at consumers and builders. Additionally, the federal government collaborates domestically and internationally in knowledge exchange and network-building. For example, Canada leads the IEA taskforce on Net Zero Energy Buildings.

Barriers, government actions impact and risk

Many technologies for improving energy efficiency in buildings are economical, proven to lower the total cost of ownership and lead to potentially large domestic benefits. Barriers to adoption are a combination of demand barriers and product barriers arising from Canada's highly fragmented markets and regulatory framework.

Demand barrier. The low demand for high-volume energy products and technology is the result of: 1) low energy costs that limit return on investment in new technologies; 2) the high use of US and offshore components that have few if any energy-efficiency requirements; and 3) a lack of education in municipalities on opportunities to increase market awareness.

Market fragmentation exacerbates the problem. Canada's diverse climate, geography and small population lead to small individual markets, making it difficult to reach economies of scale. With the enforcement of housing and building energy codes under provincial jurisdictions, there is no incentive to adopt a uniform federal code. Municipalities also make independent decisions about building energy policy, leading to further fragmentation.

Other barriers to demand include a lack of methodology to quantify the benefits (social, environmental, and economic) of energy-efficiency technologies in Canada. This makes it difficult to argue persuasively for energy-efficiency adoption and against Canada's growing reliance on US imports. It also makes it difficult to gain support for much needed domestic improvements in energy-efficiency standards.

Additional government action could be considered to overcome these barriers to adoption. To address market fragmentation, the federal government could:

- Establish a consensus with the industry on long-term equipment-efficiency standards

- Invest in and support federal-provincial efforts to create a national building efficiency code and suite of energy, environmental, and economic decision support tools
- Create early adoption programs similar to the R-2000 programs for the commercial building sector
- Build an Office of Energy Research and Development (OERD) funding model to facilitate dialogue and cooperation between federal agencies (e.g. NRCan, Environment Canada, Infrastructure Canada, PWGSC, NRC) to support municipalities in energy-efficiency investments.

Product barrier. A large number of small and medium enterprises (SMEs) serve the building energy efficiency markets, making the market so highly competitive that most businesses do not have the resources for R&D. These businesses also compete with products from the United States that are largely geared to the US climate rather than Canada's, which further decreases Canada's growth in energy efficiency.

Compounding the problem is the government's short funding cycles that limit sustained efforts to move technologies toward commercialization, and instead create a "valley of death" between product demonstration and mass adoption.

Additional government action could be considered as, without action, the Canadian market will continue to be fragmented and strongly influenced by US markets. The government could work with industry and foreign partners to:

- Build consortia in the housing sector supply chain that will accelerate market penetration of energy-efficiency technologies in domestic and international markets
- Explore strategic international supply chain alliances to encourage domestic energy technology manufacturing and R&D investments
- Consider innovative tax mechanisms to encourage foreign energy R&D and manufacturing investment in Canada.

It could also consider direct investment, such as funding allocations and interdepartmental collaborations to support strategic business and technology investments that will help companies overcome the "valley of death".

ENERGY-INTENSIVE INDUSTRIAL PROCESSES: ENERGY EFFICIENCY IN INDUSTRIAL PROCESSES

Canada's provincial and federal government activity today

The federal government provides baseline standards for industrial efficiency through BLIERS and has funded some R&D for certain industrial equipment improvements. Additionally, NRCan and the Canadian Industry Program for Energy Conservation (CIPEC) help companies reduce their energy intensity by offering both financial support and knowledge sharing.

Barriers to innovation and potential government actions

Some of Canada's best opportunities lie in increasing the energy efficiency of industrial processes, thus reducing costs and heightening the competitiveness of Canadian products abroad. Increases in energy efficiency can be achieved through incremental improvements in existing processes or the introduction of new disruptive processes and technologies. Both face market and product barriers that the Canadian government could help businesses overcome and free them to build their domestic capacity to a level that allows entry into export markets.

Adoption of EE processes by industrial companies

Market structure barrier. EE industrial processes are often economically attractive but less frequently adopted due to risk aversion, low domestic energy rates, a focus on short-term returns and, in the case of smaller businesses, a lack of awareness around the benefits of energy-efficient processes and how to implement them.

Additional government action could be considered as the government is uniquely positioned to overcome barriers by providing incentives and education and fostering collaboration.

Incentives and regulations, like graduated power rates, energy audits, and tax breaks, reward industrial plants that take risks when implementing new EE technology. This approach places the burden of improvement on the government, which, in effect, would be partially subsidizing new capital expenditures.

A second approach is to address the lack of awareness around the benefits of energy-efficiency technologies. Many small and medium enterprises do not have

the resources to assess, plan, implement, and monitor energy efficiency. By creating programs that address each of these steps (for an example, see the Netherlands case study in the *Appendix*), the government can help small and medium enterprises realize greater energy efficiencies.

Disruptive EE industrial processes

Product barrier. Many potentially disruptive improvements have been identified in Canadian industries:

- Steel – remove the coking process and capture waste heat
- Cement – derived fuels from refuse
- Paper – integrate the biorefinery and lower chemical use.

While large companies and coalitions have invested in basic industrial research and disruptive process development, mid-sized companies are reluctant to invest because of the high uncertainty of returns, the long development cycle, and the fundamental business changes required to take advantage of most disruptive technologies. While small companies often successfully develop disruptive innovation, they face barriers in scaling up.

Additional government action could be considered. Government actions to overcome barriers to disruptive innovation could be targeted at small, medium, and large businesses. Government could continue to form partnerships with industry to explore disruptive technologies in specific areas. To help mid-sized companies, the government may foster collaboration through industry forums, government-sponsored consortia, and other programs. To help small companies, government could incentivize the scale-up process by funding the growth of specific disruptive technologies in startup companies. For example, the US Department of Energy (DOE) Grand Challenges program (US $13 million with $5 million in matching funds) funds energy innovations that significantly reduce greenhouse gas emissions.

ENERGY-INTENSIVE INDUSTRIAL PROCESSES: WATER

Canada's provincial and federal government activity today

Because the water industry employs a variety of technologies, government action in this area also varies. The federal government regulates wastewater

through a range of industrial activities with the Federal Metal Mining Liquid Effluent Regulations and recently passed stricter municipal sewage effluent standards. Provincial governments also regulate certain water effluents. For example, Alberta has treatment standards for oil sands wastewater, and Quebec requires closure plans and financial guarantees for the management of tailings from oil sands operations. Additionally, federal, provincial, and municipal governments have stringent drinking water standards.

Barriers to innovation and potential government actions

Demand for water technologies and services will be high ($515 billion) in 2020. Regulations for drinking and discharge water are increasingly stringent internationally, creating demand for services that incorporate efficient and cost-effective treatment technology. The major barriers to Canadian competitiveness are a lack of demand for Canadian engineering services internationally and the need to develop new water treatment technologies.

Upgrading municipal and industrial water treatment plants

Demand barrier. The export of Canadian services (construction, upgrading, and operation) in industrial and municipal water treatment technologies is limited by international demand. Utilities are risk averse or unable to afford upgrading treatment systems to meet newer, more stringent regulations.

Additional government action could be considered. To increase the competitiveness of Canadian companies, the government could raise industrial and municipal clean and wastewater standards on a schedule ahead of the United States and other countries. This could include incentives to adopt new technologies by matching utility spend. To comply with the higher standards, utilities would have to invest in new water treatment technologies that create a domestic market for water treatment technology in Canada and that attract domestic and foreign investment in their water treatment innovation. In the long run, Canada would benefit from improved water quality and could gain a competitive advantage in the global market for water treatment technologies.

Water treatment technology and equipment

Product barrier. Energy-efficient and low-chemical water treatment technology requires further R&D and pilot testing for commercialization. Water service

companies and utilities require extensive pilot testing and third-party safety certification. Private companies have been successful in Canada and have created the regional water hub in Ontario where many global technology market leaders have originated.

The government's actions are currently sufficient, with a healthy mix of publicly funded and industrial R&D existing in the water hub. However, as the water market (for both services and technology) consolidates in the 2020 time frame, Canadian expertise and IP are at risk of being acquired before sustainable economic and job growth occurs. Therefore, government action might best focus on creating retainable commercial growth.

ENERGY-INTENSIVE INDUSTRIAL PROCESSES: WASTE TO ENERGY

Canada's provincial and federal government activity today

Government activity in waste to energy (WTE) is restricted to standards and regulations. The federal and provincial governments have emissions standards, and Ontario has particularly stringent A-7 guidelines for incinerators. Provinces differ on the designation of WTE as waste diversion: Alberta designates WTE as diversion, Ontario does not, and others are undecided. Most of Canada has landfill tipping fees, but these are low in most municipalities, making WTE uneconomical.

Barriers to innovation and potential government actions

Incineration with energy recovery is used widely in the European Union where high tipping fees and strict waste-sorting regulations (which enable incinerators to operate at higher efficiency than a mixed waste stream) make small, municipal operations economically feasible.

Many jurisdictions, such as Canada and the United States, do not have such strict regulations or economic support for waste and require a new technology that can to efficiently convert mixed waste to energy. Canada is currently developing waste-to-energy (WTE) technologies with this capability.

The Canadian government can encourage the growth of this technology and its eventual use in Canada and export to other markets by continuing to fund RD&D and removing regulatory and market structure barriers to the adoption of these technologies in Canada.

WTE technology development

Product barrier. The development of Canadian WTE technologies is limited by R&D and pilot-scale testing, which are required before utilities will adopt them. For example, new technologies, like plasma gasification, require testing to meet air and land disposal regulations.

The government's actions are currently sufficient. Government programs have identified new WTE technologies and have aided in pilot funding and scale-up. If these technologies are successful, the role of entities like Export Development Canada (EDC) could help increase their global competitiveness.

WTE technology adoption

Market structure barrier. One way to achieve global competitiveness is to have Canadian companies first develop their technologies domestically, and then export them to global markets. In Canada, domestic adoption of WTE technologies has been low compared with the European Union because both high tipping fees and sorted waste streams are required to make the current generation of incinerators economically feasible.

Additional government action could be considered. The government has several options to overcome the market structure barrier and increase Canada's WTE competitiveness in global markets. First, increased tipping fees or a FIT would spur WTE adoption, as it has in the European Union, and improve the social perception of waste control. However, consumers may not be willing to accept the increased cost of disposal.

Another option would be to finance short-term adoption, thus enabling WTE companies to innovate in ways that would lower costs. This may give Canadian companies an additional advantage by becoming best in class for cost reductions for the higher-value export market. The risk with this option is the not-in-my-backyard (NIMBY) effect with WTE locations; however, initial pilots could be held away from urban areas, enabling comprehensive testing of air quality.

TRANSPORTATION: NEXT-GENERATION AUTOMOBILES

Canada's provincial and federal government activity today

Canadian governments offer funding, incentives, and regulations to support the next-generation automobile industry. Most R&D funding comes from the federal government, but several provinces, including British Columbia, Quebec, and Ontario, offer tax breaks for the purchase of electric vehicles and are building charging stations through pilots managed by public utilities.

Most regulatory activity is federal and involves fuel economy standards. Canada's average standards for light-duty fleet vehicles are harmonized with US corporate average fuel economy (CAFE) standards through 2016. Similar standards have been proposed for heavy-duty vehicles through 2016. They are currently under review.

Barriers to innovation and potential government actions

Canada has strong companies that are competitive in the global automotive supply and manufacturing market. To remain competitive through the shift to EV technologies, these companies will need to continue innovating by adopting new materials and technologies, supply chains (e.g., new battery and motor technology companies), and businesses (e.g., EV charging infrastructure). The Canadian government can play a unique role by fostering innovations that enable the industry to promote domestic adoption of EVs and build sufficient capacity to export manufactured EV components.

Fuel efficiency and lightweighting technologies

Cost barrier. Manufacturers will delay investments in fuel efficiency and lightweighting technologies in view of consumers' focus on performance, safety, features, and price, and the higher upfront costs can only be recovered with high fuel prices or government subsidies.

Additional government action could be considered. While manufacturers are researching powertrain and lightweighting improvements, innovation could be stimulated by government action. A possible action that would help drive innovation by Canadian auto suppliers would be to increase fuel-efficiency regulations. To counter the industry's likely objection that the additional cost would be passed on to the consumer, the government could tie such regulations to

vehicle cost. For example, added costs associated with the newer technology could require a payback period of 5 years or less in reduced fuel spending for the consumer. Another option is to foster collaboration between industries – e.g., offering Canada's aluminum industry the incentive to produce specialty material grades for lightweighting.

Electric motor raw materials

Cost barrier. Rare-earth magnets are a critical cost component in electric motors, and they will become increasingly important as EV and hybrid drivetrains are more widely adopted. China has established a low-cost rare-earth supply that has stifled rare-earth investments in other countries and given China so strong a position in electric motor manufacturing and technologies that competition in this segment is almost non-existent. As a result other OEMs are worried and are beginning to search for rare-earth substitutes. The anticipation of high demand has prompted multiple proposals to restart mining for rare-earth in the United States, Canada, India, and South Africa in the next few years.

Additional government action could be considered. Although market forces are driving investment in rare-earth mining, careful regulation by the government will be required to: 1) encourage the large investments needed to develop new environmentally-friendly mining techniques; and 2) maintain Canada's social licence to operate through adopting strict water and land remediation standards.

EV charging infrastructure

Market structure barrier. Like CNG/LNG vehicles, to succeed, electric vehicles require extensive investment in recharging infrastructure. The uncertainty of charging standards, rapid technological advancement, and competition among manufacturers has slowed the adoption of a unified charging standard. Manufacturers are also choosing to delay infrastructure investment until demand for rapid charging is greater.

Additional government action could be considered. Rapid adoption will have domestic economic benefits, and it will prepare Canada's auto suppliers and manufacturers for competition in global markets. The government is uniquely positioned to lower the risk and capital required for large infrastructure investments by participating in private-public partnerships.

TRANSPORTATION: CNG/LNG FLEETS

Canada's provincial and federal government activity today

Most government activity in CNG/LNG involves regulations and investments in R&D and pilot projects. The federal government funded R&D for CNG/LNG forestry fleets, and British Columbia invested in fueling stations and offered incentives for adoption of NG vehicles. On the regulatory side, the federal government has set standards for the safety of vehicles and fueling stations, and provincial governments offer permits for site installations. For example, Alberta and British Columbia approved permits to Shell for a $250 million investment in an LNG plant and corridor of fueling stations.

Barriers to innovation and potential government actions

With low projected natural gas prices, the economics of natural gas vehicles is favourable in the long term for heavy vehicles. Unlike light vehicles, trucks have few alternatives to reduce GHGs and can be operated in fleet or long haul configurations.

Adoption of NG vehicles and refueling infrastructure

Market structure barrier. Canada has the technology to convert its truck fleet to natural gas. Westport is a Canadian company that has developed a diesel-natural gas truck engine technology. It has partnered with several major diesel truck manufacturers, including Cummins in the United States, and is positioned to enter North American and EU markets in the coming years.

Natural gas companies in Canada have also begun to consider ways of driving domestic demand for natural gas, as natural gas exported to the United States faces a significant discount because of high transportation costs. Several Canadian natural gas companies have expressed interest in building the natural gas infrastructure in Canada, including refueling stations along west-to-east truck routes.

Vehicle and fleet owners are the remaining barrier. They are reluctant to invest the premium required to upgrade vehicles to natural gas because of a perceived natural gas price risk. Many of these vehicle owners were active participants in the attempted conversion to natural gas in the 1990s and saw the refueling infrastructure dwindle during the natural gas price spikes of the early 2000s.

Additional government action could be considered. Accelerated adoption of natural gas in vehicles will create domestic cost benefits and could help Canada develop natural gas vehicles and infrastructure in advance of the rest of North America, giving it a competitive advantage when the rest of the continent follows. Although natural gas suppliers have shown willingness to build infrastructure, the reluctance of fleet owners to buy natural gas vehicles is a result of past experience and perceived risk. The government is uniquely positioned to counter this market failure and position Canada for long-term competitiveness by: 1) providing incentives for adopting natural gas vehicles; 2) harmonizing Canadian and US natural gas vehicle and infrastructure standards; and 3) continuing outreach and training on the economics of natural gas and the natural gas supply.

TRANSPORTATION: FUEL CELL SYSTEMS

Canada's provincial and federal government activity today

Federal and provincial governments have provided funding for projects, including the BC Hydrogen Highway. Transport Canada's ecoTECHNOLOGY for Vehicles (eTV) Program tests the safety of hydrogen vehicle technology. A one-time investment from SaskEnergy, Saskatchewan Research Council, and NRCan funded a fleet of hydrogen trucks and a fueling station; however, the project ended last year and no expansion or continuation has been proposed.

Barriers to innovation and potential government actions

Hydrogen fuel-cell technology has two major barriers: the catalyst in the fuel cell is expensive, and currently there is no market for infrastructure technology.

Hydrogen fuel cell vehicles

Product barrier. Hydrogen fuel cells are used in many applications, including aerospace and industrial settings (e.g., fuel cell forklifts). The barrier to fuel cell use in light and heavy commercial vehicles is cost and performance. Currently, the conversion of hydrogen to electricity (and vice versa) uses platinum and palladium-based catalysts, which are very expensive. Today's research is focused on finding less expensive alternatives to platinum, such as polymers and membranes. A second problem is that, like electric batteries, charging or

discharging fuel cells too quickly can cause heat build-up and damage. Expanding the range over which fuel cells can operate is a second major area of research in fuel cells.

The government's actions are currently sufficient. The Canadian government has made long-term investments in hydrogen fuel-cell research, building world-class hydrogen fuel cell research centres, and supporting university R&D that attracts industry investment. A major automobile FCV consortium is working to bring FCV costs down and is targeting to start mass production in 2030.

Fuel cell infrastructure

Market structure barrier. The infrastructure associated with fuel cells (FCV refueling, stationary power, or grid storage applications) is crucial to the widespread use and adoption of fuel cells. Because fuel cell vehicles appear to be so far in the future, industry is reluctant to invest in large-scale vehicle infrastructure. Also, since the time frame to switch to a more sustainable, and potentially more economically profitable hydrogen economy is likely post-2030, current investments in hydrogen infrastructure are minimal.

Additional government action could be considered. Although long-term (post-2030) economic value can be generated by switching to a hydrogen economy, today's market does not adequately support the construction of the essential infrastructure. This presents a possible avenue for government action, namely, to encourage long-term planning that would ease the transition from a finite fossil fuel economy to a hydrogen/electricity economy. The major risk of investing in fuel cell infrastructure would be delays in reducing the costs of hydrogen applications (like FCV) and therefore locking up public dollars that could be used elsewhere in a shorter time frame. The Canadian government may want to hold off on further investment until industry and export markets have made commitments to hydrogen infrastructure. Since Canada is already ahead of the competition, waiting for this development is not likely to hurt its competitive position.

CONSIDERATIONS FOR PRIORITIZING ACTIONS

Although we have identified barriers for technology areas where government actions could be warranted, Canada has limited resources and will need to prioritize its support. This prioritization is outside the scope of this project, but

the team has identified questions in four areas that will be helpful as the government decides which actions to pursue.

1. Impact. To what extent can the government make a meaningful difference for each technology area? Are there effective instruments government can deploy for a particular area? Some technology barriers will be more or less responsive to government action, and some barriers may require actions that are outside the jurisdiction of the acting government or require too much financial or political capital.

2. Timeline. How long will it be until government action can make an impact? How long should government continue to be involved, particularly in providing direct subsidies or other funding support? An ideal portfolio of actions would contain a balance of short- and long-term actions that bring economic benefit within the next 5 to 10 years, while positioning Canada as a competitive energy player in 10 years and beyond.

3. Interdependence. What impact might actions have on other technology areas (e.g., investing in electric vehicles may increase demand for electricity-producing renewables)? How do actions for a particular technology area affect other government objectives (e.g., climate change, economic development, provision of public goods)? How might actions of other governments affect the effectiveness of Canadian government actions? A portfolio of actions would create cross-benefits between technologies and also support the diverse responsibilities that a government holds, including providing public goods and addressing external issues.

4. Risk. Do selected actions ultimately add up to a portfolio that adequately balances risk? Does the success of an action rely upon coordinated action with other stakeholders (i.e., provinces) and is their cooperation likely? The final portfolio could be constructed with an eye toward balancing safe investments with strategic bets.

Careful consideration of the four factors identified here – impact, timeline, interdependence, and risk – is integral to the development of a viable portfolio of actions that will drive the development of Canadian competitiveness and grow Canada into a major energy technology power.

PERFORMANCE METRICS TO ASSESS ENERGY SECTOR DEVELOPMENT

Once the Canadian government has selected the instruments to support energy technology development, it is important to measure and monitor the effectiveness of these actions through a variety of metrics. These metrics can be grouped into quantitative or qualitative and leading or lagging. The leading or lagging designation tells if the metric either anticipates a future event (leading) or indicates the outcome of a past event (lagging).Typically, quantitative lagging indicators are the most accessible and definitive measure of success (see Appendix: GDP/Jobs Economic Impact Model for details describing the impacts on the recommendations here on quantitative lagging indicators); however, leading indicators are more helpful from a monitoring perspective.

Quantitative leading metrics are easier to obtain and analyze and are used to anticipate future changes in a sector. These metrics split into two categories:

- Metrics most useful for new or young companies and industries include: research activity, such as bibliometrics in specific technology areas or energy R&D spending, whose numbers are usually available from Statistics Canada; patent activity in the number filed or percentage of patent duplication; industry creation activity, such as deal activity in venture capital or mergers and acquisitions, and the number of new companies or number of companies going public; and the performance of supported companies, such as growth in revenue, employees, joint ventures, and partnerships) and finances (return on capital employed, return on investment, and EBITDA).
- Metrics most useful for mature companies and industries include the performance of supported technology areas, such as share of global markets, revenues, employees, joint ventures, and partnerships; and industry activity, such as new foreign company subsidiaries and joint ventures and partnerships.

Quantitative lagging metrics are also relatively easy to obtain and analyze but tend to indicate past changes in a sector. These metrics include: direct and indirect GDP and jobs volume and growth, which may be available only at the sector level; power and fuel costs for consumer and industrial use; trade volume and growth, which is available at a subsector level; student interest in energy-related fields, such as the percentage of enrollment and the number of graduates;

Qualitative metrics, while more difficult to measure, are also important indicators. Leading metrics include: formation of hubs; technology transfer activity; industry activity, such as new industry associations or conferences; and media activity, such as discussion in articles and blogs, and investor market reports.

Qualitative lagging metrics include: energy security, community resilience, and labour efficiency.

The above is a wish list of example metrics. We recommend using a combination of different categories to assess the health of the sector and changes in its performance, the effectiveness of government actions, and anticipated changes in the sector. Depending on the availability of specific metrics at different levels of granularity, we suggest using a subset (or substitutes) for monitoring and tracking purposes.

Appendix: Sources

As outlined in Exhibit 3, we used several sources to assess the trends, risks, and opportunities across technology areas, including McKinsey's *Carbon Abatement Curve, Resource Revolution* report, *Global Energy Perspective* model, market research, as well as interviews with McKinsey and other technology experts. We also had numerous working sessions with Canadian federal and provincial government agencies, and were able to leverage the many reports these agencies shared with us.

The McKinsey *Carbon Abatement Curve* details the total cost of carbon abatement for a wide range of energy technologies. It is covers the GHG emissions of a given technology and identifies technologies that have both large abatement potential and economic benefits.

The McKinsey *Resource Revolution* report describes global socioeconomic and industrial trends through the middle of the century, and details specific projections of future demand, including the doubling of the global automobile fleet by 2030, the large increases in food and water usage in the BRIC countries, and the large expansions in urban infrastructure that will accompany the growth of major metropolitan areas.

It also describes some of the trends in resource discovery, such as the rise in expense resulting from the decreasing yield of oil projects, the flat rate of major mining discoveries despite a quadrupling of mine exploration spend, the expansion of cities into arable land, and the 30 percent increase in water supply that will be required by 2030 to meet population needs.

It points out several new trends, including the increased energy required to obtain water from lowering groundwater tables and large scale water transfer projects, the large amount of steel and other resources required by unconventional renewable energy sources, and the effective increase in energy content in many products due to carbon pricing.

The McKinsey *Global Energy Perspective* model forecasts global energy demand growth and energy supply mix using a variety of assumptions and analyses derived from McKinsey studies, external sources such as the IEA World Energy Outlook reports, IHS the EU Energy Roadmap and Enerdata.

The team conducted industry research, drawing upon a variety of sources including company websites, industry and association reports, and materials provided by NRCan and other government agencies.

The team also conducted a series of interviews with McKinsey technology area and policy experts, as well as experts in Canadian government agencies, industry associates and venture capital firms (Exhibit 10).

s.19(1)
s.20(1)(b)
s.20(1)(c)

Appendix: GEP Model Assumptions

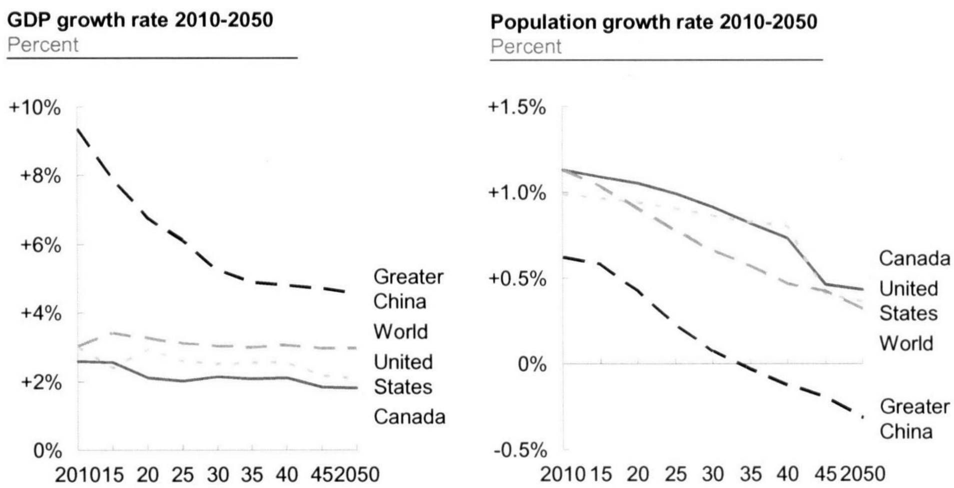
The McKinsey Global Energy Perspective model forecasts global energy demand growth and energy supply mix on a regional level using a variety of assumptions and analyses. It was used to compare the relative size (on the order-of-magnitude scale) of different technology areas, quantify domestic and foreign energy demand and assess the sensitivity of trends to regulatory and technology assumptions. The model was not used to predict oil or gas prices, which are inputs to the model. It identifies regional trends and allocations but not how differences between regions are resolved.

In this report, we concentrated on three regions: Canada, the United States, and Asia (including China, Japan, and Southeast Asia). The model describes markets at the level of major commodities and generating sources (e.g., oil, gas, coal, nuclear, wind, solar) but not subsectors (e.g., conventional vs. unconventional oil, lighting vs. HVAC), distribution technologies (e.g., LNG/GTL and smart grid) or trade flows (oil, gas and coal imports and exports). In many cases, other data sources were used to supplement our assessment of economic potential, including the market sizes of specific areas along technology value chains and the value accessible to Canada.

The model assumes modest GDP (Exhibit 11) growth (3 percent overall, 2 percent in Canada, with more rapid growth in Asia, derived from IHS Global Insight forecasts), continuing population growth trends, and that demand will scale with GDP and population growth.

EXHIBIT 101

GEP model regional GDP and population growth assumptions



SOURCE: McKinsey Global Energy Perspective, Global Insight

The model also makes several assumptions (shown in Exhibits 12 to 14) about oil, gas, and coal prices (using IEA 2010 WEO actuals and 2011 forecasts), carbon pricing in various regions (in this case reaching $50 per ton in the United States, and $30 per ton in China, from McKinsey sources), and RES power mix (2010 actuals from Enerdata, capex assumptions from EU Roadmap 2050). The model also assumes full compliance with power generation mandates and emissions goals where applicable, and that supply is always able to meet demand (i.e., no market failures).

EXHIBIT 111

GEP model commodity price assumptions (1/2)

		2010	2020	2030	2040	2050	Comments/Sources
Oil prices USD/bbl	Crude oil	78	109	117	124	133	IEA 2010 and 2011 WEO New Policies scenario
	Heavy fuel oil[1,2]	51	71	77	81	89	Derived from crude oil using multiplying factor
Gas prices (selection) USD/mmbtu	U.S.	5.1	5.1	6.1	7.1	7.1	Barnett core shale gas price range
	Canada	5.1	6.1	7.1	8.1	8.1	From 2020 and beyond: US gas price + $1 as transportation cost
	China	6.0	8.6	11.2	11.7	12.3	50% LNG (Japan)+50% Russian prices+$1 as transportation cost
	India	5.0	8.5	12.1	12.9	13.7	75% LNG (Japan)+25% Russian prices
	Japan	10.0	13.4	14.4	15.2	16.2	LNG import price forecasted on historical prices from Bloomberg
CO_2 prices USD/t	US	0	20	30	40	50	CO_2 price forecasts from IEA 2011 WEO New Policies scenario (US, Canada, China, India, Japan)
	Canada	0	20	30	40	50	
	China	0	10	23	30	30	
	India	0	0	0	0	0	
	Japan	0	20	30	40	50	

- Demand model is price **insensitive**, i.e. does not depend on fuel prices (coal, oil, gas). It is only in power model that fuel prices are taken as an input.
- CO2-price is only considered as an input in demand model to implement CCS levers in Global Consensus scenario, **NOT in Reference scenario**

1 Fuel oil prices are kept globally flat for all region **except ArabGulf**
2 Heavy fuel oil prices derived from crude oil by multiplying with a factor of **0.66**

SOURCE: McKinsey Global Energy Perspective, IEA 2010 (for 2010 actuals) and 2011 WEO

EXHIBIT 112

GEP model commodity price assumptions (2/2)

		2010	2020	2030	2040	2050	Comments/Sources
Coal prices USD/t	U.S.	78.2	72.6	75.6	77.6	80.2	Average price for coastal regions according to internal expert for 2010-2020 and for future decades its extrapolated with IEA WEO 2011 new policy scenario growth rate
	Canada	99.2	106.3	109.3	111.3	113.8	Based on IEA 2010 and 2011 WEO New Policies scenario price for imported steam-coal and extrapolation to 2050
	China	78.2	91.5	94.5	96.4	99.0	Average price for high grade coal (inland and coastal); price based on import parity according to internal expert for 2010/2020 and extrapolated with IEA WEO 2011 new policy scenario growth rate
	India	77.2	80.7	83.7	85.6	88.2	Average price for coastal regions according to internal expert for 2010/2020 and extrapolated with IEA WEO 2011 new policy scenario growth rate
	Japan	99.2	106.3	109.3	111.3	113.8	LNG import price forecasted on historical prices from Bloomberg

SOURCE: McKinsey Global Energy Perspective, IEA 2010 (for 2010 actuals) and 2011 WEO

EXHIBIT 113

GEP model government targets and power generation capex assumptions

		2010	2020	2030	2040	2050	Comment/Sources
Government targets RES[1] GW per decade	US	N/A	70	0	0	0	▪ Based on known regulation, renewable energy action plans either from local R&I or government websites ▪ There are 2 ways that RES is built: – through govt mandates (forced capacity), irrespective of cost considerations, or – through economic fundamentals (cost optimization)
	Canada	N/A	4	0	0	0	
	China	N/A	200	0	0	0	
	India	N/A	17	0	0	0	
	Japan	N/A	8.1	0	0	0	
Solar PV Euro/W	US	2.3	1.1	0.8	0.7	0.6	▪ 2010 values based on lower end of EU Roadmap 2050 ▪ Forward going prices based upon capex model, where learning rate is ~15% ▪ Prices refined based on expert opinion of Krister Aarnesen
	Canada	2.3	1.1	0.8	0.7	0.6	
	China	1.9	0.9	0.6	0.5	0.4	
	India	1.9	0.9	0.6	0.5	0.4	
	Japan	2.4	1.1	0.8	0.7	0.6	
Wind Onshore Euro/W	US	1.1	1.0	1.0	1.0	1.0	▪ 2010 and 2050 values based on EU Roadmap 2050 ▪ Future pricing based ~0% Learning rates as technology is already quite mature ▪ Source: Expert Interviews
	Canada	1.1	1.1	1.0	1.0	1.0	
	China	0.9	0.8	0.8	0.8	0.9	
	India	1.0	0.9	0.8	0.9	0.9	
	Japan	1.1	1.1	1.0	1.0	1.0	

- Government RES targets are assumed to be fully implemented in the power model.
- No targets available after 2020.
- Other RES deployment as output from the model is based on cost optimization in the model

1 Solar, wind, biomass, (excl. hydro)

SOURCE: McKinsey Global Energy Perspective, IEA 2011 WEO

To determine the mix of technologies used for power generation, the model uses technology cost curves developed by various McKinsey practices and the EU Roadmap 2050 (Exhibit 15). It assumes that power sources are chosen to minimize total operating cost, taking into account build cost, cost of renewable energy credits, and other factors (Exhibit 16). The power technology build cost is modeled by considering several regional factors, including overall GDP, capex, and productivity increase (Exhibit 17).

EXHIBIT 114

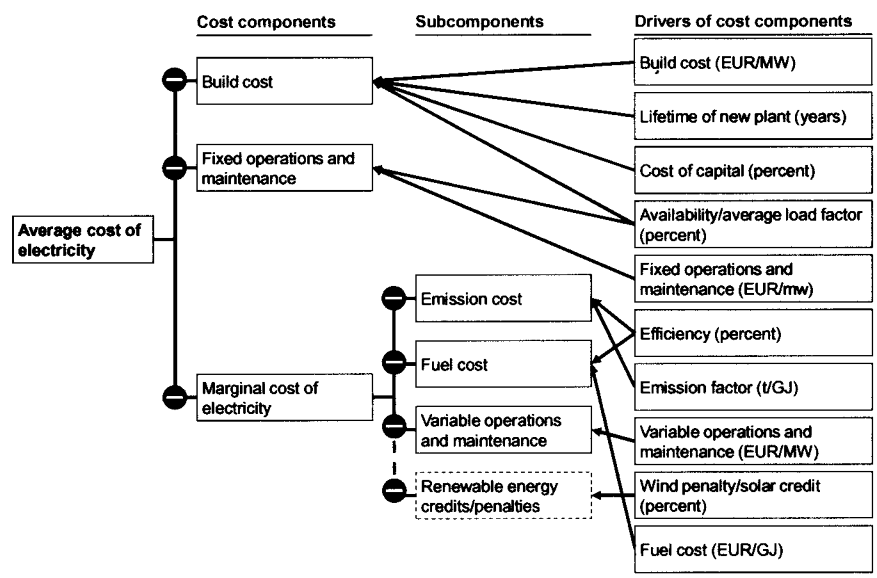
GEP model power generation capex assumptions

		2010	2020	2030	2040	2050	Comment/Sources
Coal Euro/W	US	1.5	1.4	1.3	1.3	1.2	Based on EU Roadmap 2050, adjusted for regional differences in labor costs
	Canada	1.5	1.4	1.3	1.3	1.2	
	China	0.6	0.6	0.7	0.8	0.9	
	India	0.8	0.7	0.8	0.8	0.9	
	Japan	1.5	1.4	1.4	1.3	1.3	
CCGT Gas Euro/W	US	0.6	0.6	0.6	0.6	0.6	
	Canada	0.6	0.6	0.6	0.6	0.6	
	China	0.4	0.4	0.4	0.4	0.5	
	India	0.5	0.4	0.5	0.5	0.5	
	Japan	0.8	0.7	0.7	0.7	0.7	
Nuclear Euro/W	US	3.7	3.7	3.7	3.6	3.6	Based on EU Roadmap 2050 with upward adjustments after Fukushima incident, regionally differentiated based on labor cost differences
	Canada	3.7	3.7	3.7	3.7	3.6	
	China	1.4	1.4	1.7	2.1	2.5	
	India	2.9	2.7	2.9	2.9	3.1	
	Japan	3.8	3.8	3.8	3.8	3.8	

SOURCE: McKinsey Global Energy Perspective, IEA 2011 WEO

EXHIBIT 15

The GEP Model forecasts decisions on capacity build-out and dispatch based on average cost of electricity and marginal cost

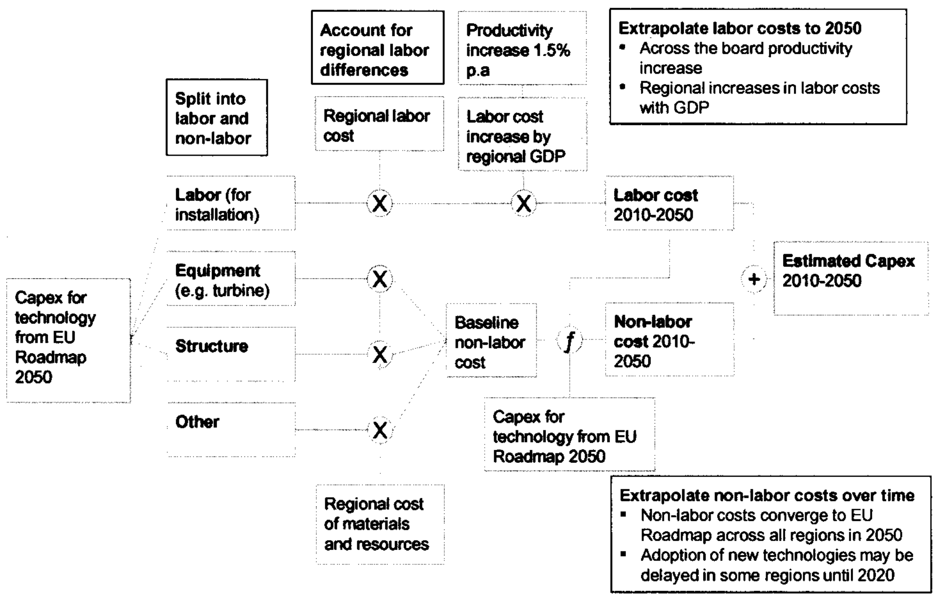


SOURCE: McKinsey Global Energy Perspective

The model derives the energy demand in the transportation sector by: 1) forecasting vehicle demand using GDP, population, and usage patterns (Exhibit 18); 2) forecasting the mix of electric, gasoline, and diesel light and heavy vehicles using assumptions from the McKinsey Automotive Practice; and 3) calculating fuel usage for the vehicle fleet across segments and regions (Exhibits 19 to 21).

EXHIBIT 16

Power generation technology capex model[1]



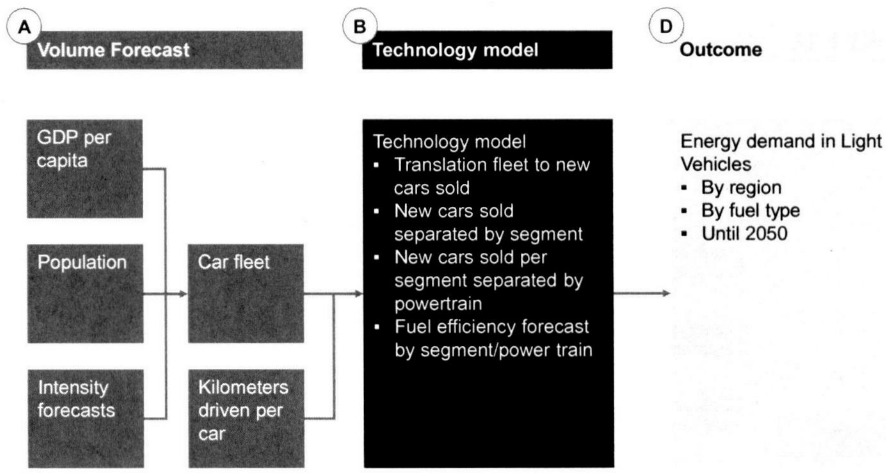
1 In rapid technology adoption case, overall cost falls with doubling of capacity (e.g. 25% decrease per 2x capacity)

SOURCE: McKinsey Global Energy Perspective

EXHIBIT 17

LIGHT VEHICLES

Light vehicles high-level model overview

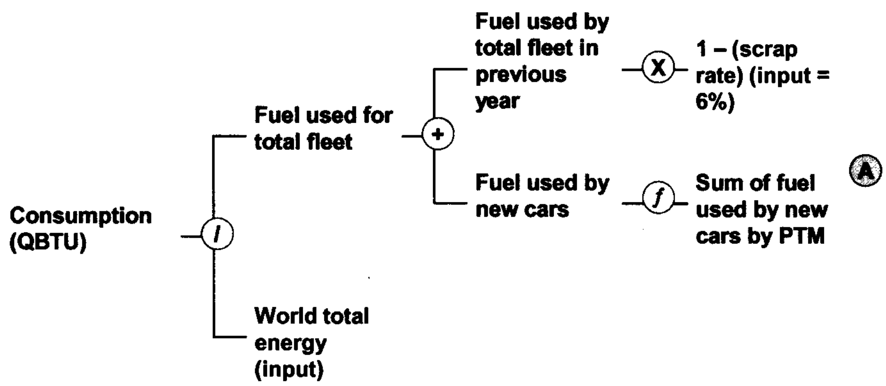


SOURCE: McKinsey Global Energy Perspective

EXHIBIT 18

LIGHT VEHICLES

Logic tree – Light Vehicles (1/3)

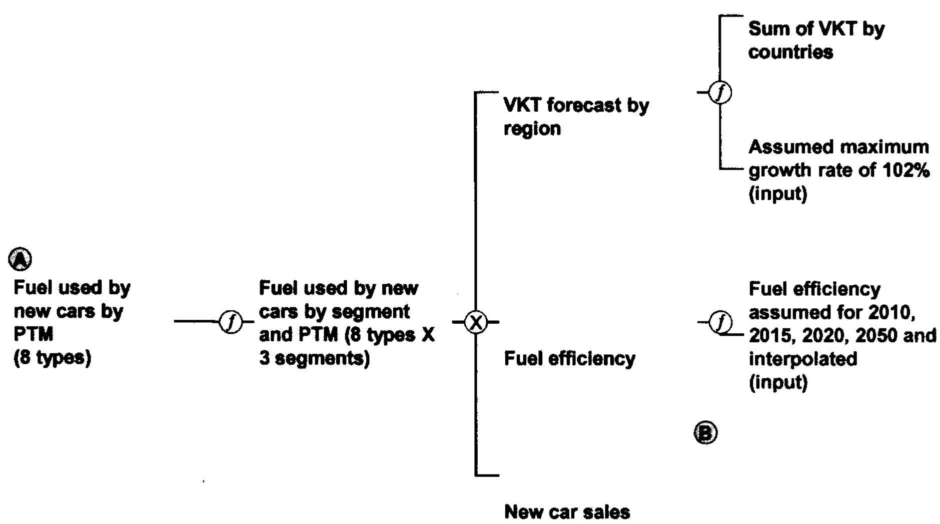


SOURCE: McKinsey Global Energy Perspective

EXHIBIT 19

LIGHT VEHICLES

Logic tree – Light Vehicles (2/3)

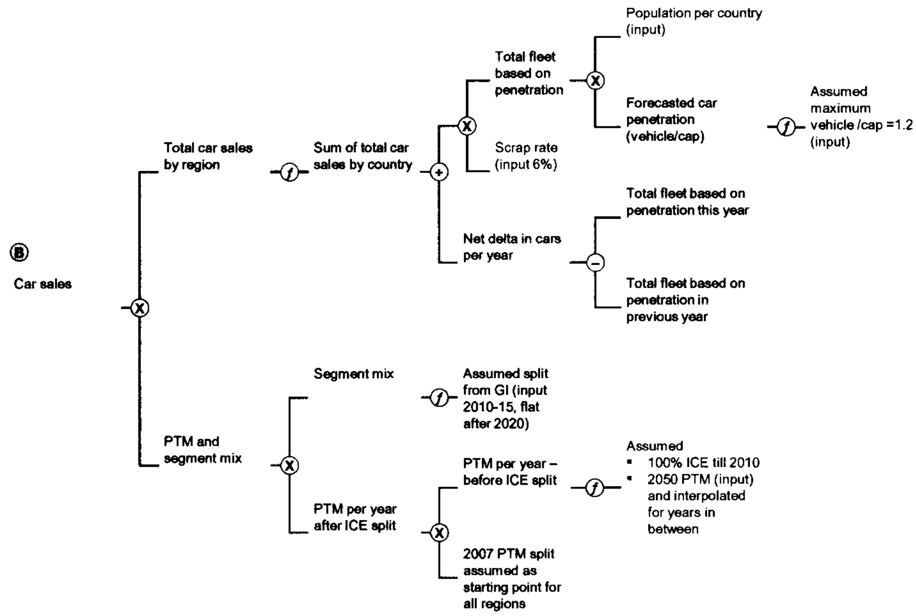


SOURCE: McKinsey Global Energy Perspective

EXHIBIT 20

LIGHT VEHICLES

Logic tree – Light Vehicles (3/3)



SOURCE: McKinsey Global Energy Perspective

In many cases, changing the assumptions had predictable, modest effects on the rates of CCS and other technology adoption (Exhibit 22). For instance, increasing the carbon price by 4 times to $160 per ton in 2050 caused gas CCS adoption to double in North America and coal CCS adoption to double in Asia. However, in the scenario of rapid technology adoption, CCS is disadvantaged and adoption falls across the board by 50 percent. Further details of this analysis are shown in Exhibits 23-26.

EXHIBIT 21

Sensitivity to assumptions about oil and gas prices, carbon regulations, and technology adoption rates was tested by running alternate scenarios

	1 Sensitivity to oil and gas price	2 Sensitivity to technology adoption	3 Sensitivity to carbon regulations
GDP	▪ **Stable**, approximately 3% per annum long term	▪ **Stable**, approximately 3% per annum long term	▪ **Stable**, approximately 3% per annum long term
Technology	▪ Typical technology cost curve follows ~15% cost reduction/doubling of capex spend	▪ **Accelerated,** typical technology curve follows 25% cost reduction per doubling of capex spend	▪ **Accelerated,** Typical technology curve follows 25% cost reduction per doubling of capex spend
Regulation	▪ 2050 carbon prices reach $50/ton in US and Canada, $30/ton in China (WEO 2011)	▪ 2050 carbon prices reach $50/ton in US and Canada, $30/ton in China (WEO 2011)	▪ **Strict adoption of CO_2 regulation:** 2050 carbon prices reach $160/ton in all regions (calculated to reach 2 degree target)
Canada specific	▪ Heavy fuel oil price 0.8 of crude price ▪ Canadian gas price 85% of US gas prices	▪ Heavy fuel oil price 0.8 of crude price ▪ Canadian gas price 85% of US gas prices	▪ Heavy fuel oil price 0.8 of crude price ▪ Canadian gas price 85% of US gas prices

EXHIBIT 22

The increased heavy fuel oil and discounted gas price scenario

		2010	2020	2030	2040	2050	Comment
Oil prices USD/bbl	Crude oil	78	109	117	124	133	Crude oil price from IEA 2011 WEO New Policies scenario
	Heavy fuel oil	51	71	77	81	89	Original scenario (0.6x crude multiplier)
	Heavy fuel oil	**62**	**87**	**94**	**99**	**106**	**Increased 0.8 multiplier used**
Gas prices (selection) USD/mmbtu	U.S.	**4.3**	5.1	6.1	7.1	7.1	2010 price based on **NRCan input (originally 5.1)**
	China	6.0	8.6	11.2	11.7	12.3	50% LNG (Japan)/50% Russian prices
	Canada	3.7	4.3	5.2	6.0	6.0	Original scenario (US gas price +$1 due to transportation cost)
	Canada	**3.7**	**4.3**	**5.2**	**6.0**	**6.0**	**Gas price 85% of US and similar growth factor on future decades**

SOURCE: McKinsey Global Energy Perspective

EXHIBIT 23

The accelerated technology adoption scenario

		2010	2020	2030	2040	2050	Comment/Sources
Solar PV Euro/W	US	2.3	1.0	0.6	0.4	0.3	**Learning rate assumed to be 25% per doubling of capacity**
	Canada	2.3	1.0	0.6	0.4	0.3	
	China	1.9	0.8	0.4	0.3	0.3	
	India	1.9	0.8	0.4	0.3	0.3	
	Japan	2.4	1.0	0.6	0.5	0.4	
Wind Onshore Euro/W	US	1.1	1.0	0.8	0.8	0.8	**Learning rate assumed to be 10% per doubling of capacity**
	Canada	1.1	1.0	0.8	0.8	0.8	
	China	0.9	0.8	0.7	0.7	0.7	
	India	1.0	0.7	0.7	0.7	0.7	
	Japan	1.1	1.0	0.9	0.8	0.8	

SOURCE: McKinsey Global Energy Perspective

EXHIBIT 24

The strict CO_2 regulation scenario

		2010	2020	2030	2040	2050	Comments/Sources
Original scenario[1] CO_2 prices USD/t	US	0	20	30	40	50	**CO2 price forecasts from IEA 2010 and 2011 WEO New Policies scenario**
	Canada	0	20	30	40	50	
	China	0	10	23	30	30	
	India	0	0	0	0	0	
	Japan	0	20	30	40	50	
Strict CO2 regulation scenario CO_2 prices USD/t	US	0	40	60	120	160	**Aggressive CO2 price push to meet the 450 ppm CO2 target**
	Canada	0	40	60	120	160	
	China	0	20	60	120	160	
	India	0	20	60	120	160	
	Japan	0	40	60	120	160	

SOURCE: McKinsey Global Energy Perspective, IEA 2011 WEO

EXHIBIT 25

High CO_2 prices increased CCS adoption and decreased overall fuel demand but did not significantly change overall trends

Scenario	Observations
1 **Oil and gas prices**	▪ Doubling of NG CCS and some adoption of coal CCS in Canada as a result of lower NG price assumption (prices only affected in Canada)
2 **Technology adoption rate**	▪ Decrease in global fuel demand due to increased efficiency – (0.5% CAGR vs 1.1% in the original case) ▪ Asia still the fastest growing fuel demand (0.9%), while US and Canada have negative (-0.1 and -0.3%) growth rates ▪ Solar adoption accelerated by 10 years; wind adoption unchanged ▪ Hydro still the largest power source in Canada ▪ Industry and buildings growth slow or flat across the board; chemicals sector is still the largest growth area in the industry ▪ Global gas and coal CCS less adoption by 50%
3 **Carbon regulation**	▪ Decrease in global fuel demand growth to 0.3% CAGR ▪ Hydro is still the largest power source in Canada, but most new demand is met by RES ▪ Doubling of gas CCS in NA, doubling of coal CCS in China from original case ▪ Negative growth in industry and buildings in US and Canada, very slow growth in Asia

Appendix: GEP Model Results

A summary of the main findings of the model is shown in Exhibit 27. The main findings for the model across energy sectors are shown in Exhibits 28-36. The results for alternative scenarios are shown in Exhibits 37-44.

EXHIBIT 26

McKinsey's proprietary forecast models were used to generate a view of energy supply and demand dynamics across sectors/geographies

		Sector/Fuel	Perspective
Supply	❶ Fossil Fuels	▪ Coal ▪ Oil and gas ▪ Natural Gas ▪ Electricity	▪ 1.1% p.a. total energy growth for next 40 years (Canada: 0.3%, US: 0.5%, Asia: 1.5%), 90% growth from power generation in Asia ▪ Fuel sources remain stable in Canada, while US shifts from oil (36 to 28 QBTU 2010-50) to gas (15 to 23 QBTU 2010-50)
Supply	❷ Renewables and Clean Energy	▪ Solar ▪ Wind, Hydro ▪ Bioenergy ▪ CCS	▪ Rapid growth in renewable power production (7.7% p.a. worldwide) driven by cost reductions, especially in US and China ▪ Canada power mix continues to be dominated by hydro, then nuclear ▪ Strong long term (2030-2050) growth in CCS driven by CO_2 prices
Distr.	❸ Distribution	▪ Coal, oil and LNG transport ▪ Electrical storage and distribution	▪ Supply and demand tight for coal, driving large imports into India (while China relies on domestic and EU decrease coal use) ▪ Effective integration of RES into grids requires grid electrical storage ▪ Expansion in oil and gas pipelines to support increased demand
Demand	❹ Buildings and Communities	▪ Commercial ▪ Residential	▪ Modest increases in commercial and residential energy usage in Canada and US, but high demand increase in Asia commercial and residential energy usage with the rise of middle class consumers ▪ Shift to electricity as energy source (from 30% to 50%)
Demand	❺ Energy-intensive Industrial Processes	▪ Chemicals ▪ Metals and mining ▪ Pulp and Paper	▪ Most growth in Asian industrial consumption with emergence of middle-class consumers ▪ Chemicals sector grows rapidly compared to other sectors ▪ Paper, metals/mining stable in Canada & US, growing in China
Demand	❻ Transportation	▪ Road vehicles ▪ Rail ▪ Marine ▪ Aviation	▪ Transportation fuel needs will drop in Canada and US due to efficiency, but increase in Asia due to new middle class ▪ EVs expected to take off in 2030-2050, BEV in Asia ▪ Strong CNG adoption in US heavy vehicles (~50% in 2050)

SOURCE: McKinsey Global Energy Perspective Model

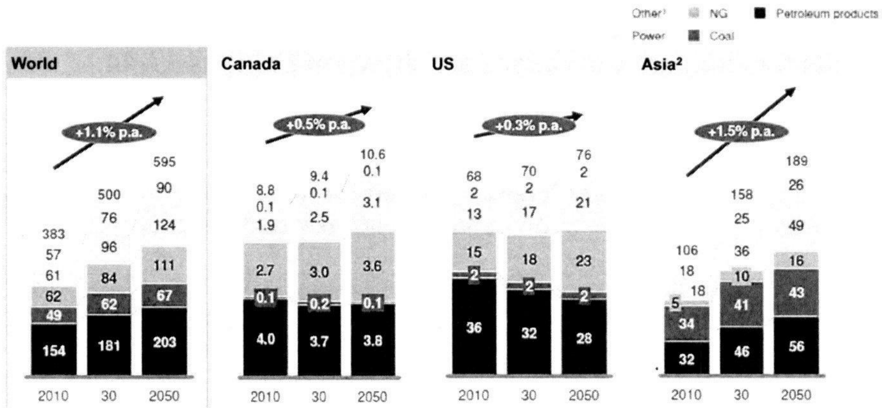
EXHIBIT 27

❶ FOSSIL FUELS

Global energy demand for fossil and other fuel types

Final Energy Demand[1], QBTU

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



- Globally stable growth across all fuels expected, with increase in RES
- Increase in use of gas, flat oil demand
- Decrease in oil demand, increase in gas demand
- High increase across all fuels expected

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan
3 Other includes use of biomass, renewables etc

SOURCE: McKinsey Global Energy Perspective

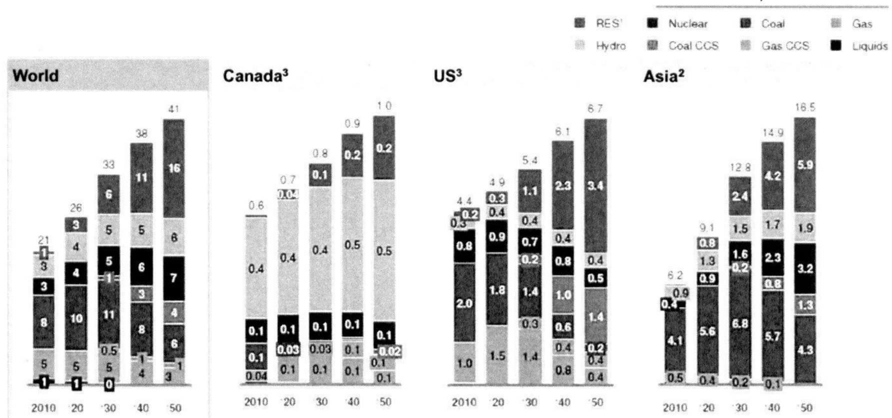
EXHIBIT 28

❷ RENEWABLES AND CLEAN ENERGY

Electricity production fuel mix

Fuel mix of power production[4]('000 TWh), percent

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



Main Drivers

- Growth from Non-OECD
- Learning curves drives RES

- Hydro to retain majority of power mix
- Growing share of Renewables from 2030

- Initial increase in natural gas use but declining due to continued decrease in RES cost

- Coal growth strong until 2030, after which RES, CCS and nuclear become more economical

1 Renewable Energy Systems (RES) are Solar PV, Solar CSP, Wind Onshore, Wind Offshore, and Biomass
2 Asia includes India, China and Japan
3 Carbon-Capture-and-Storage (CCS) enabled by CO_2-prices in US, China and Canada; no CO_2-prices assumed in other non-OECD countries
4 All of RES, Nuclear, Hydro are used for electricity production; Coal, gas and liquids used in power production are included for comparison purposes

SOURCE: McKinsey Global Energy Perspective

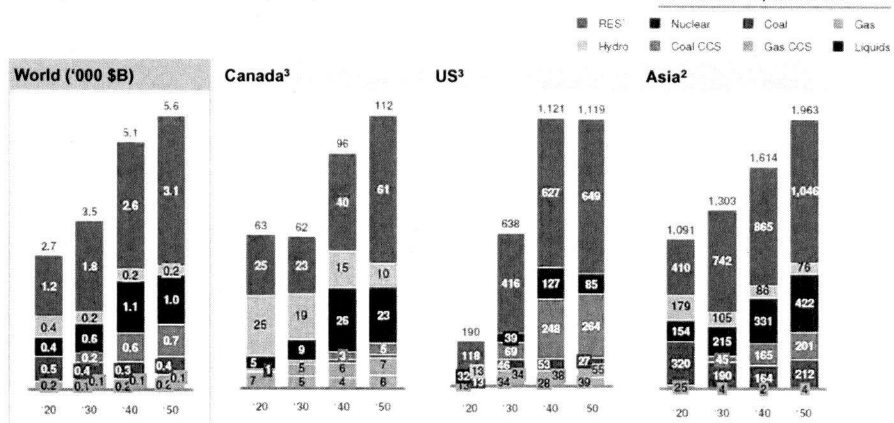
EXHIBIT 29

❷ RENEWABLES AND CLEAN ENERGY

Capital expenditures on electricity production

Capital Expenditure for new Capacity $B

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



Main Drivers

- Growth from Non-OECD
- Learning curves drives RES

- Retirement and RES to drive high new investment costs by '40 & '50

- RES and CCS expenditures begin in 2020-2040

- After initial coal investment, large investments in RES and nuclear, some in CCS

1 Renewable Energy Systems (RES) are Solar PV, Solar CSP, Wind Onshore, Wind Offshore, and Biomass
2 Asia includes India, China and Japan
3 Carbon-Capture-and-Storage (CCS) enabled by CO_2-prices in US, China and Canada; no CO_2-prices assumed in other non-OECD countries

SOURCE: McKinsey Global Energy Perspective

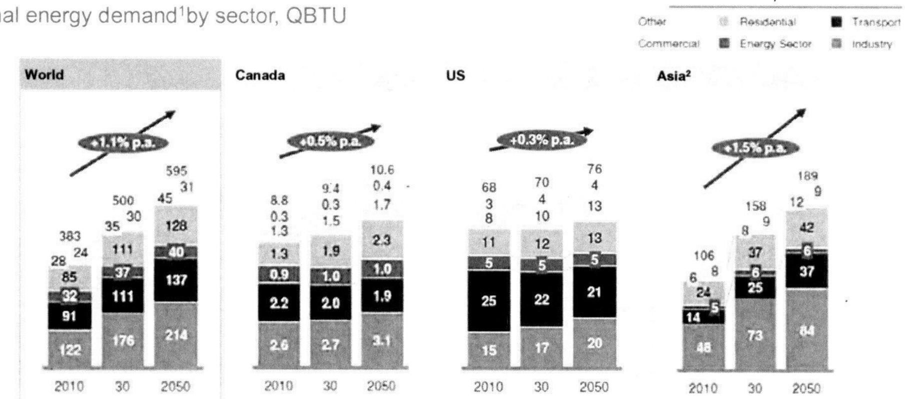
EXHIBIT 30

❹ FINAL ENERGY DEMAND - SECTORS

Energy demand across building, transportation and industrial sectors

Final energy demand[1] by sector, QBTU

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



- Stable growth across all sectors expected
- Strongest growth in Industry and Transport sectors
- Modest growth excepted in buildings, driven by GDP and population increase

- Almost flat growth across all sectors expected, except for buildings

- Almost flat growth across all sectors in US

- All sectors, are expected to have a huge growth in energy demand due to high economic growth

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan

SOURCE: McKinsey Global Energy Perspective

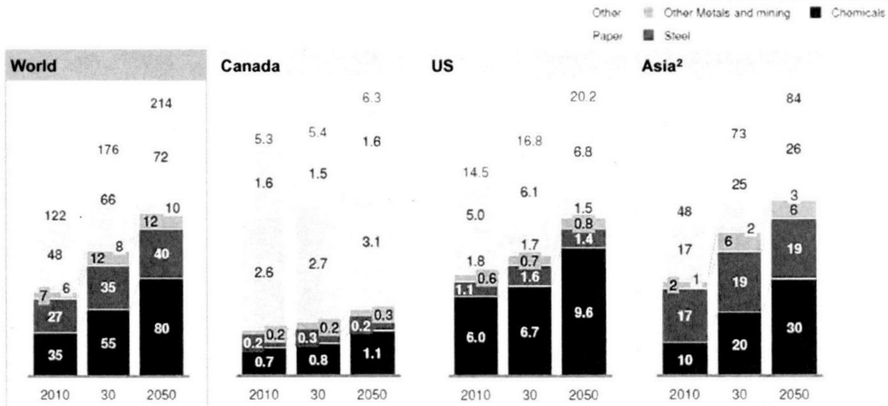
EXHIBIT 31

5 ENERGY INTENSIVE INDUSTRIAL PROCESSES

Energy demand across industrial sectors

Final energy demand by sector[1], QBTU

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



- Chemical and Steel are the key growth industries
- Largest growth in chemicals industry, modest or flat growth in other areas
- Largest growth in chemicals industry
- Chemical is expected to grow 3X by 2050 in Asia

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan

SOURCE: McKinsey Global Energy Perspective

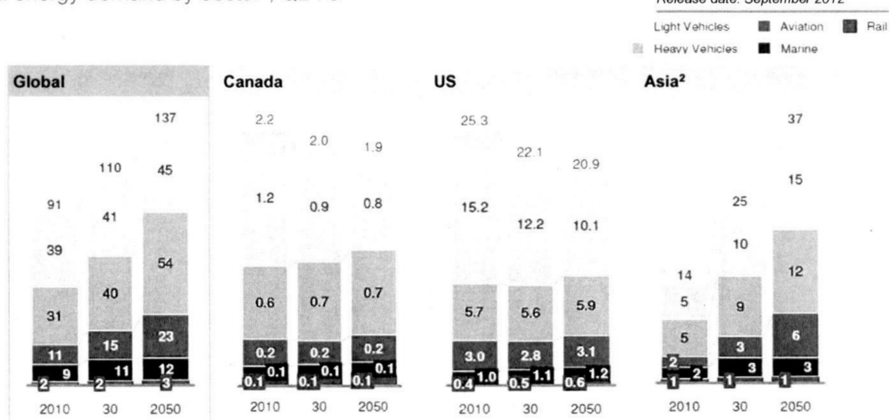
EXHIBIT 32

6 TRANSPORTATION

Energy demand across transportation sectors

Final energy demand by sector[1], QBTU

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



- LV and HV constitute ~ 80% of total Transport
- HV is expected to grow more than the LV sector due to EV
- Decrease in demand across LV, due to increase in efficiency and tech development
- Decrease in demand across LV, due to increase in efficiency and tech development
- Large increases in demand across LV, HV and Aviation sectors driven by economic growth

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan

SOURCE: McKinsey Global Energy Perspective

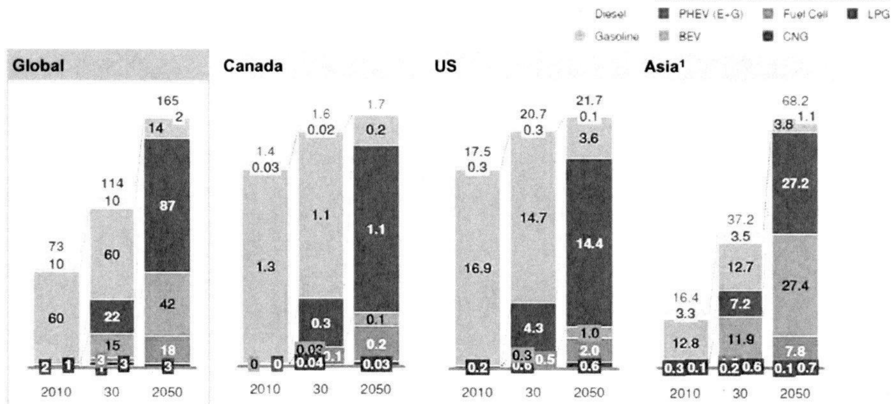
EXHIBIT 33

6 TRANSPORTATION

Demand for light vehicle types

New Sales of Light vehicles, millions

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



- Global: Governmental regulation; Fuel prices; Technology development
- Canada: Mass PHEV adoption expected 2030-2050
- US: Canadian and US market have similar drivers and adoption patterns
- Asia: EV adoption later than in US/Canada; BEV adoption high due to gasoline/electricity cost differential

1 Asia includes India, China, and Japan

SOURCE: McKinsey Global Energy Perspective

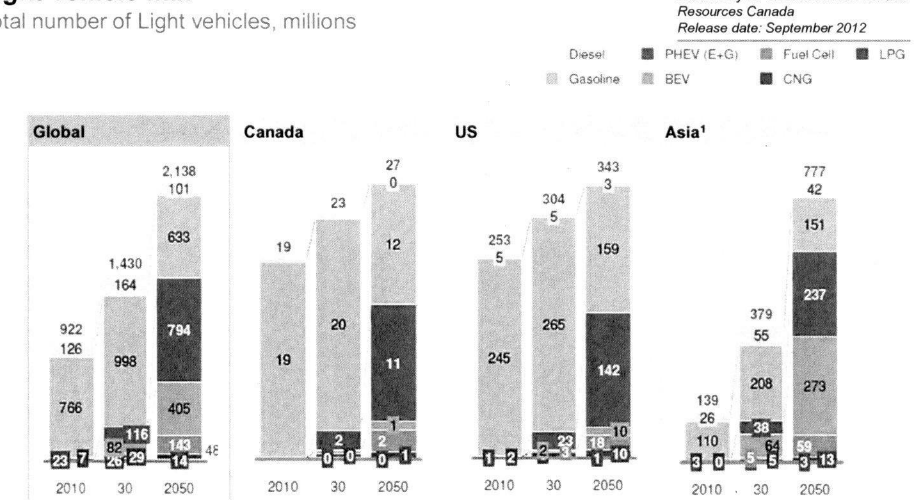
EXHIBIT 34

6 TRANSPORTATION

Light vehicle mix

Total number of Light vehicles, millions

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



- Global: Governmental regulation; High penetration of EV
- Canada: Reduction in ICE; Increase in PHEV cars
- US: Reduction in ICE, esp gasoline; Increase in PHEV cars
- Asia: Total fleet is expected to become **6X** by 2050, compared to 2010 levels

1 Asia includes India, China, and Japan

SOURCE: McKinsey Global Energy Perspective

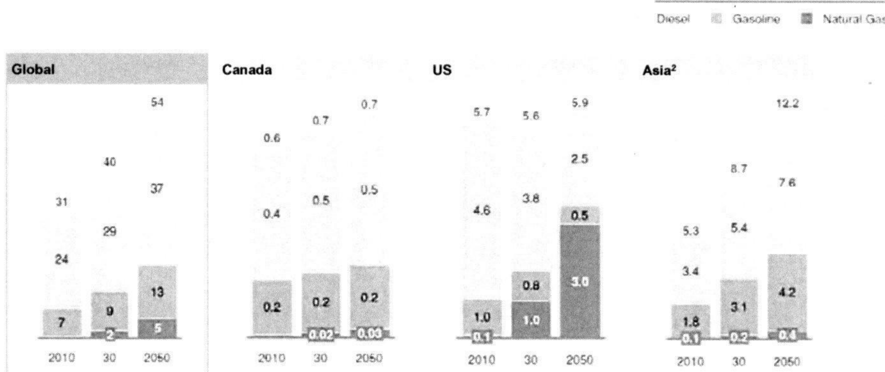
EXHIBIT 35

❻ TRANSPORTATION

Energy demand for heavy vehicle types

Final energy demand[1] for Heavy vehicle sector, QBTU

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



- Global: Diesel is the main fuel for Heavy Vehicles (HV), i.e., trucks
- Global shift from diesel to natural gas expected due to decrease in natural gas prices/increase in diesel prices
- Canada: Heavy vehicle mix relatively static
- US: Shift from diesel to natural gas driven by low cost of natural gas in US
- Asia: High increase in demand expected in Asia, due to high gdp growth rate

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan

SOURCE: McKinsey Global Energy Perspective

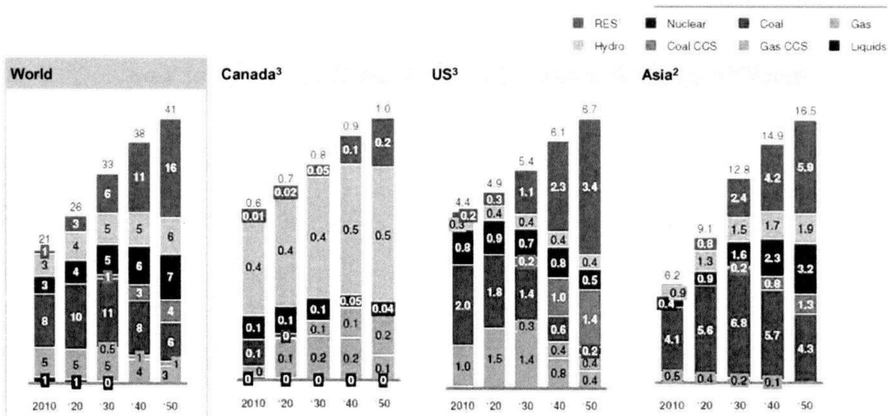
EXHIBIT 36

❷ RENEWABLES AND CLEAN ENERGY – HIGH HEAVY OIL, DISCOUNTED GAS SCENARIO

Electricity production fuel mix

Fuel mix of power production[4] ('000 TWh), percent

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: October 2012



Main Drivers

- World: Growth from Non-OECD
- Learning curves drives RES
- Canada: Hydro to retain majority of power mix
- Growing share of Renewables from 2030
- US: Initial increase in natural gas use but declining due to continued decrease in RES cost
- Asia: Coal growth strong until 2030, after which RES, CCS and nuclear become more economical

1 Renewable Energy Systems (RES) are Solar PV, Solar CSP, Wind Onshore, Wind Offshore, and Biomass
2 Asia includes India, China and Japan
3 Carbon-Capture-and-Storage (CCS) enabled by CO_2-prices in US, China and Canada; no CO_2-prices assumed in other non-OECD countries
4 All of RES, Nuclear, Hydro are used for electricity production; Coal, gas and liquids used in power production are included for comparison purposes
SOURCE: McKinsey Global Energy Perspective

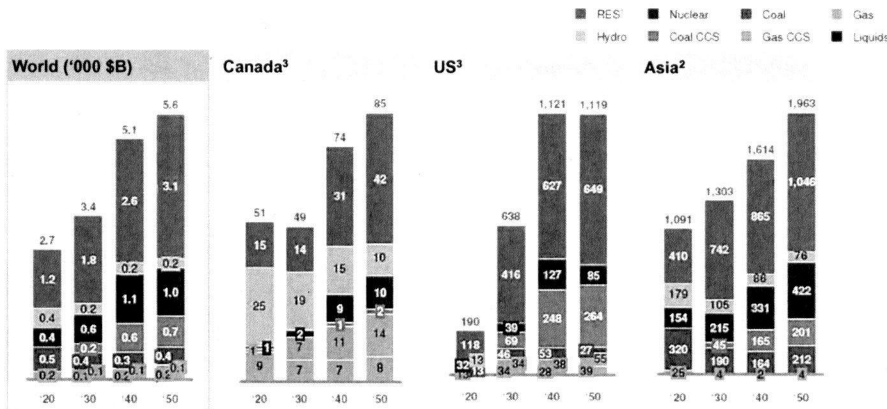
EXHIBIT 37

2 RENEWABLES AND CLEAN ENERGY – HIGH HEAVY OIL, DISCOUNTED GAS SCENARIO

Capital expenditures on electricity

Capital Expenditure for new Capacity $B

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: October 2012



Main Drivers

World:
- Growth from Non-OECD
- Learning curves drives RES

Canada:
- Retirement and RES to drive high new investment costs by '40 & '50

US:
- RES and CCS expenditures begin in 2020-2040

Asia:
- After initial coal investment, large investments in RES and nuclear, some in CCS

1 Renewable Energy Systems (RES) are Solar PV, Solar CSP, Wind Onshore, Wind Offshore, and Biomass
2 Asia includes India, China and Japan
3 Carbon-Capture-and-Storage (CCS) enabled by CO_2-prices in US, China and Canada; no CO_2-prices assumed in other non-OECD countries

SOURCE: McKinsey Global Energy Perspective

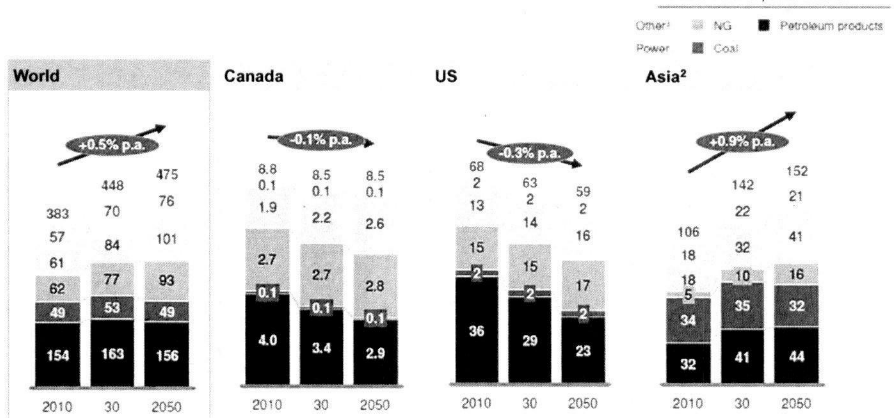
EXHIBIT 38

1 FOSSIL FUELS – ACCELERATED TECHNOLOGY ADOPTION SCENARIO

Global energy demand for fossil and other fuel types

Final Energy Demand[1], QBTU

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



World:
- Flat demand for oil and coal
- Increase in power and gas demand

Canada:
- Increase in use of gas, and power
- Decrease in oil demand

US:
- Decrease in oil demand, increase in gas demand

Asia:
- Increase across all fuels, whereas small decrease in coal demand

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan
3 Other includes use of biomass, renewables etc

SOURCE: McKinsey Global Energy Perspective

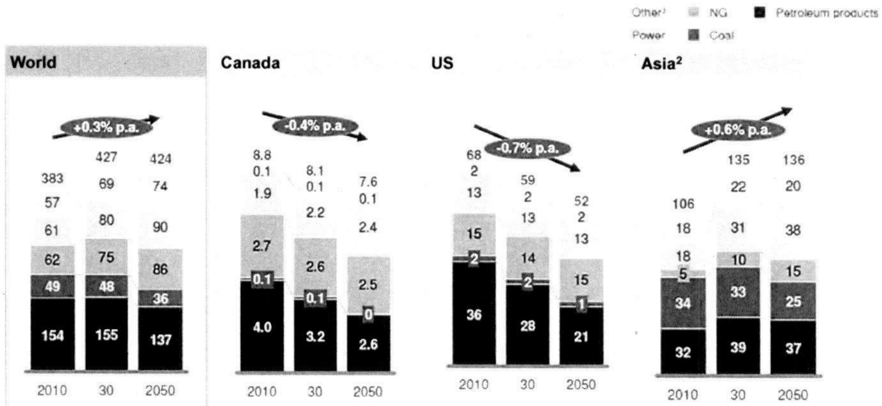
EXHIBIT 39

1 FOSSIL FUELS – STRICT CARBON REGULATION SCENARIO

Global energy demand for fossil and other fuel types

Final Energy Demand[1], QBTU

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



- Decrease in oil and coal demand in long term
- Increase in power and gas demand

- Increase in use of gas and power demand
- Sharp decrease in oil demand

- Decrease in oil demand
- Increase in gas demand

- High increase in power and gas demand
- Decrease in oil and coal demand

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan
3 Other includes use of biomass, renewables etc

SOURCE: McKinsey Global Energy Perspective

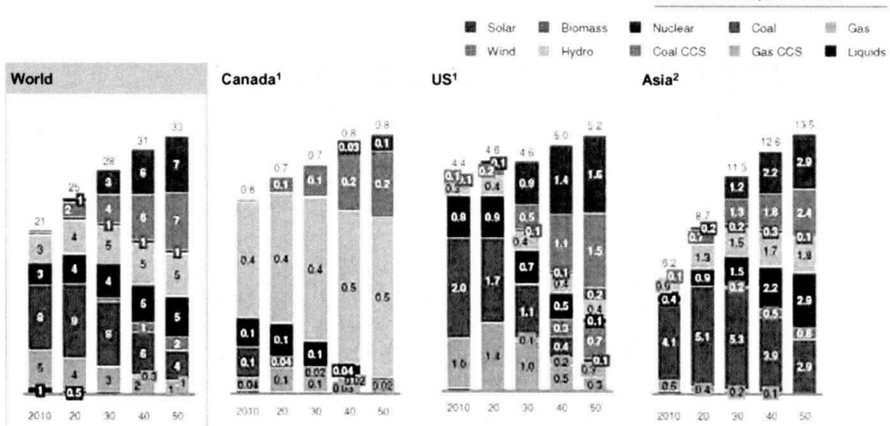
EXHIBIT 40

2 RENEWABLES AND CLEAN ENERGY – ACCELERATED TECHNOLOGY ADOPTION SCENARIO

Electricity production fuel mix

Fuel mix of power production[3] ('000 TWh), percent

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



Main Drivers

- Growth from Non-OECD
- Learning curves drives RES

- Hydro to retain majority of power mix
- Majority of production from Renewables by 2050

- Initial increase in natural gas use but declining due to continued decrease in RES cost

- Coal growth strong until 2030, after which RES, CCS and nuclear be-come more economical

1 Carbon-Capture-and-Storage (CCS) enabled by CO2-prices in US, China and Canada; no CO_2-prices assumed in other non-OECD countries
2 Asia includes India, China and Japan
3 All of RES, Nuclear, Hydro are used for electricity production; Coal, gas and liquids used in power production are included for comparison purposes

SOURCE: McKinsey Global Energy Perspective

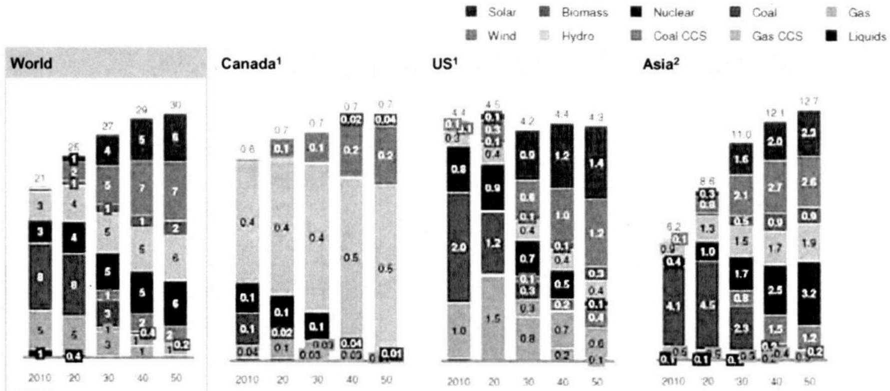
EXHIBIT 41

❷ RENEWABLES AND CLEAN ENERGY – STRICT CARBON REGULATION SCENARIO

Electricity production fuel mix

Fuel mix of power production[3] ('000 TWh), percent

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



Main Drivers

- Growth from Non-OECD
- Learning curves drives RES

- Hydro to retain majority of power mix
- Majority of production from Renewables by 2050

- Initial increase in natural gas use but declining due to continued decrease in RES cost
- Small dip in '30 due to Energy efficiency gains

- Coal growth strong until 2020, after which RES, CCS and nuclear become more economical

1 Carbon-Capture-and-Storage (CCS) enabled by CO_2-prices in US, China and Canada; no CO_2-prices assumed in other non-OECD countries
2 Asia includes India, China and Japan
3 All of RES, Nuclear, Hydro are used for electricity production; Coal, gas and liquids used in power production are included for comparison purposes
SOURCE: McKinsey Global Energy Perspective

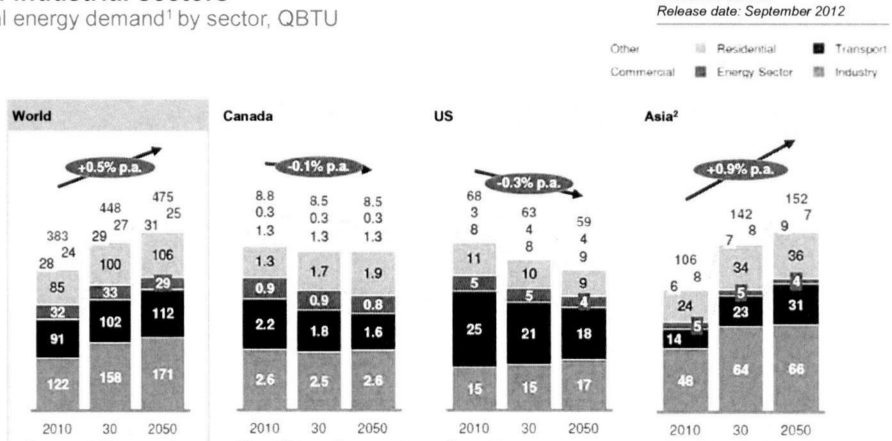
EXHIBIT 42

❹ FINAL ENERGY DEMAND – SECTORS – ACCELERATED TECHNOLOGY ADOPTION SCENARIO

Energy demand across building, transportation and industrial sectors

Final energy demand[1] by sector, QBTU

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



- Decrease in Energy sector, due to RES in power
- Mild growth in Industry and Transport sectors
- Low growth excepted in buildings due to higher energy efficiency

- Almost flat growth across all sectors expected, with a sharp decrease in transport sector

- Overall decrease in energy demand, due to decrease in transport, whereas almost flat growth across all other sectors

- All sectors, are expected to grow in energy demand due to high economic growth

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan
SOURCE: McKinsey Global Energy Perspective

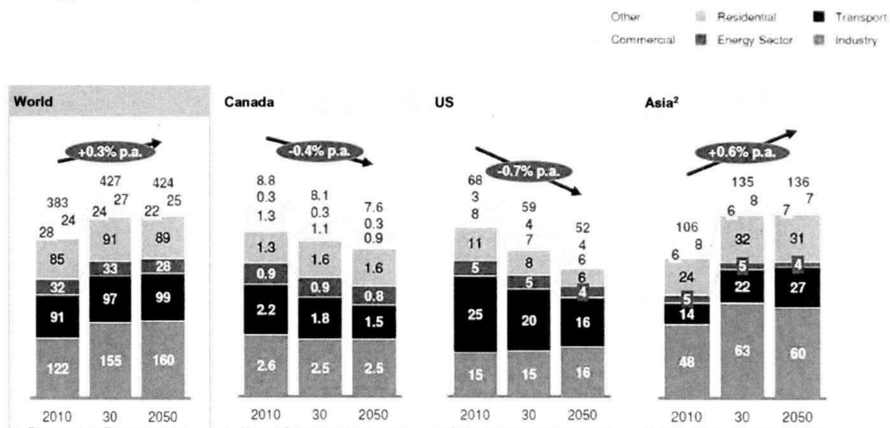
EXHIBIT 44

4 FINAL ENERGY DEMAND – SECTORS – STRICT CARBON REGULATION SCENARIO

Energy demand across building, transportation and industrial sectors

Final energy demand[1] by sector, QBTU

This document was prepared exclusively for discussion with Natural Resources Canada
Release date: September 2012



World:
- Decrease in Energy sector, due to RES in power
- Mild growth in Industry and Transport sectors
- Flat demand in buildings due to aggressive energy efficiency

Canada:
- Almost flat growth across all sectors expected, with a sharp decrease in transport sector

US:
- Overall decrease in energy demand, due to decrease in transport, buildings and energy sectors

Asia[2]:
- All sectors, are expected to grow in energy demand due to high economic growth

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan

SOURCE: McKinsey Global Energy Perspective

Appendices – case studies

CANADA

As a comparison for the case studies in the rest of the appendices, this section offers an overview of Canada's energy technology policies and environment. It provides some detail on the state of R&D funding, technology transfer, entrepreneur mentorship, venture capital, and export.

Canada's federal and provincial R&D funding is channeled through a number of departments, agencies, and centres. Although institutions exist to coordinate energy research,[1] the natural fragmentation of the energy sector limits coordination and leads to duplicative efforts and inefficient use of resources.

Once a technology exists, it should be transferred from the laboratory to the market. In many cases, this is accomplished through university technology transfer offices. These transfer offices, however, are a bottleneck in Canada's innovation chain, and many innovations in university research fail to yield a patent or a commercialized product. Intellectual property (IP) policies are determined on an institution-by-institution basis,[2] which creates confusing inconsistencies for entrepreneurs and inventors and impedes the commercialization process.

Established startups next need mentorship and industry connections. Innovation hubs around the world, like the Silicon Valley, accomplish this by co-locating academia and industry and forging strong ties between entrepreneurial students and experienced businesses. Canadian universities tend to have looser ties with industry and few campus incubators or mentorship programs, which leads to a limited focus on commercializing innovations.

A growing number of institutions, however, are beginning to develop these crucial mentorship networks. Universities at Waterloo, British Colombia, and Sherbrooke, for example, are pursuing programs to support student innovators.

[1] These research coordination centres have been established by both government and universities; two examples of university energy and cleantech research centres are at the University of Calgary and McMaster.

[2] Some institutions manage IP more effectively than others; the University of Waterloo is an example of a university with progressive IP transfer policies.

The government is investing heavily as well. The 2012 Federal Budget increased funding to a number of programs designed to promote mentorship and university-private sector collaboration, including the Industrial Research and Development Internship program and the Canadian Innovation Commercialization Program. Some established government programs like the Natural Sciences and Engineering Research Council of Canada have shifted their focus toward encouraging researcher-industry partnerships. Industry groups as well are making efforts; Startup Canada, for example, recently launched the Canadian Mentorship Challenge, a series of events hoping to connect 10,000 entrepreneurs with experienced mentors.

Beyond mentorship, though, small companies need capital, and Canada has run into some difficulty providing sufficient funds for its startups. In particular, Canadian companies struggle most in finding late-stage funding,[3] which leads to undercapitalization and a struggle to scale up. Furthermore, capital has fled the Canadian market rapidly; total capital raised fell 16 percent annually between 2001 and 2010, and total capital invested experienced a similar drop.

Capital flight is driven by low returns in the market and a vicious cycle of poor outcomes driving away talented fund managers and inexperienced fund managers investing poorly. Additionally, restraints on some government-sourced capital, like the requirement to distribute funds between provinces and regions, hinder investments in the best-performing companies and push down returns. Lack of capital is most problematic for Canada's economy when promising startups fail to find sufficient funding and move abroad, sell to a foreign company, or list prematurely and fail to reach their potential.[4] As shown in more detail in Exhibit 45, all three outcomes forgo possible value for Canada's economy.

Because Canada's domestic market is small, companies that develop need strong exports to grow and capture the value available in an energy technology. Today, Canada's exports are primarily low-value-add products such as raw natural

[3] On average, a US company receives $5.7 million in early-stage funding and $11.5 million – a 100% increase – in late-stage funding. In contrast, an average Canadian company receives $3.3 million in early-stage funding and only $4.1 million in late-stage funding – a 25% increase.

[4] Low TSX listing requirements give struggling entrepreneurs the option to list prematurely, a choice that leaves the business to stagnate, discourages further investment, and creates an "orphan stock". A comparison of listing requirements for TSX and NASDAQ and NYSE is available in Exhibit 46.

resources,[5] and its main export partner is the United States,[6] meaning Canada is not capturing value in prominent markets such as the European Union and developing regions. Several sources of export support are available to domestic companies. Export Development Canada offers insurance and equity and underwrites performance bonds for exporters. The Trade Commissioner Service has established offices in a number of target markets and facilitates the creation of trade relationships, although energy-specific knowledge may be limited and support is restricted to projects advancing governmental priorities. Additionally, Canadian companies need support in other areas, such as navigating international IP law and piloting their technologies in international markets with higher energy prices that make alternative energies economical.

A holistic government approach is important for addressing challenges and opportunities at all points in the innovation chain. Canada's government has made efforts to improve coordination in its policies and empower government programs to support technologies through the chain. The 2012 Federal Budget increased funding to innovation-oriented programs, including $110 million to the Industrial Research Assistance Program and $12 million to the Business-led Networks of Centres of Excellence. Additionally, a report commissioned by Natural Resources Canada in 2006, the *Examination of Federal Energy and Energy-related Environmental S&T Investments* (FEESTI), identified opportunities to improve the transparency and consistency of government support across the innovation chain.

Some unique characteristics of Canada will affect its energy technology sector and the government's efforts to support the sector. Unlike some countries described in other case studies, Canada represents diverse interests and natural resources, which complicates the development of a long-term energy vision. While large in size and diversity, Canada is also small in population and market. Next to a much larger neighbour that is culturally similar, it can become a technology-taker rather than developer and can lose intellectual property and talented entrepreneurs to its neighbour. These characteristics are important to remember when looking at Canada's energy sector and when looking at how other countries with different characteristics approach their energy sectors.

[5] For example, Canada's exports comprise 22 percent energy, 9 percent agriculture/fishing, and 5 percent forestry products.

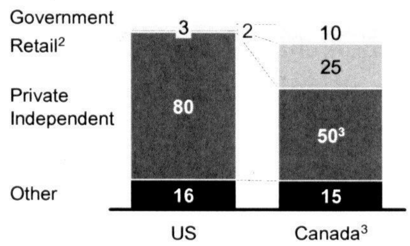
[6] Seventy-five percent of Canada's exports go the US.

EXHIBIT 43 – THE DIFFERENCES IN THE UNITED STATES AND CANADIAN VC ENVIRONMENTS ARE EVIDENT IN FINANCIAL OUTCOMES

ENERGY INNOVATION ENVIRONMENT

	Research spend	**Inventions disclosed**	**New companies formed**	**Income generated**[1]
Canada	**0.4%** of GDP *$6.1 billion*	**284** per billion spent	**8** per billion spent	***1%*** of expenditure *$60 million*
US	**0.4%** of GDP *$59.1 billion*	**349** per billion spent	**10** per billion spent	**4%** of expenditure *$2.4 billion*

Investments by type of investor
2009, Percent



Average exit price
2002-2009, Cdn $ Millions

1 Income includes recurring royalties, cashed-in equity, and other income
2 Includes individual investing in labour-sponsored funds, e.g., LSVCs
3 Includes foreign investors

EXHIBIT 44

ENERGY INNOVATION ENVIRONMENT

In general, TSX has lower listing requirements than NYSE and NASDAQ

	TSX	TSX Venture, Tier 2[1]	NYSE	NASDAQ Global Market	NASDAQ Capital Market
2-year average pre-tax income	Cdn $200,000- Cdn $300,000	$750,000 in NTA[2] or $500,000 in revenue or $2,000,000 in arms-length financing	$2,000,000	**Standard 1a.** $1,000,000 (2 out of 3 years) **Standard 2b.** n/a **Standard 3c.** n/a **Standard 4d.** $75,000,000 (2 out of 3 years)	**Standard 1a.** n/a **Standard 2b.** n/a **Standard 3c.** $750,000 (2 out of 3 years)
Market value of publicly held stock	Cdn $4,000,000 for industry Cdn $10,000,000 for technology	$75,000	$40,000,000 for IPO	**a.** $8,000,000 **b.** $18,000,000 **c.** $20,000,000 **d.** $20,000,000	**a.** $15,000,000 **b.** $15,000,000 **c.** $5,000,000
Share-holders' equity	No minimum	No minimum	No minimum	**a.** $15,000,000 **b.** $30,000,000 **c.** n/a **d.** n/a	**a.** $5,000,000 **b.** $4,000,000 **c.** $4,000,000

1 Tier 2 is for young, early-stage companies
2 Net tangible assets
SOURCE: Venture Law Corporation

[redacted]

AUSTRIA: BIOHEAT/POWER [redacted]

In the past several years, Austria identified a need for reliable, renewable energy and an opportunity in domestic heating for bioheat/power. The government uses a three-prong strategy to encourage adoption of bioheat/power – regulations, investment with incentives, and education with fostering collaboration.

Regulatory efforts focus on building codes, including heating requirements in some areas that mandate a certain fraction of building heating to come from biomass. Although most requirements in the codes are not stringent, recent government efforts have increased consistency among regional building codes and established an energy performance grading system for buildings.

The government also invests in R&D and offers subsidies at several points along the value chain. Wood harvesting is subsidized and enhanced by government initiatives to improve harvest efficiency and logistics. A combination of reduced taxes on wood used for pellet heating and high taxes on other fuels makes wood 40 to 45 percent less expensive than alternatives. To encourage homeowners to transition to wood heating, the government offers a soft loan[7] program for retrofits.

The more direct actions, regulations, and investments with incentives are balanced with more indirect actions like education and fostering collaboration. Austria's energy agency supports initiatives that encourage networking between green energy businesses to promote development and cooperation. Similar government initiatives enhance market transparency and coordinate R&D knowledge transfer. At the consumer level, homeowners can receive performance assessments for their homes and advice for capturing energy savings.

Today in Austria, biomass comprises 32 percent of renewable energy[8] consumption, and 40.5 percent if district heating is included. Austria has 7 percent of global biomass capacity, and there is a mature and effective fuel

[7] A soft loan contains concessions to borrowers, such as below-market interest rates, long repayment terms, or interest holidays.

[8] Excluding large-scale hydro plants.

delivery infrastructure that supports steady growth in the market, including 6.1 percent in 2010.

BRAZIL: ETHANOL

Through proactive investment in biofuels development and adoption, Brazil has become a global leader in biofuel technology and market penetration. The process to convert Brazil's abundant sugarcane to ethanol was well known when the 1973 oil crisis proved the dangers of oil dependence, and the government responded with a portfolio of measures to develop a supply chain and grow market demand.

Brazil's government created a national agency, the Institute of Sugar and Alcohol, to monitor and manage the development of the ethanol industry. Low-cost credit and favourable financing encouraged the sugarcane industry to increase its output of feedstock, while direct investment in infrastructure projects built up capacity to convert the sugarcane and distribute the produced ethanol. The government collaborated with the United States to exchange knowledge and create international standards.

A combination of government actions continues to create demand that provides a reliable market and revenue stream for ethanol producers. These actions include procurement of ethanol-only government fleets, mandatory blending in vehicle fuels, voluntary – followed by mandatory – manufacturing targets for ethanol-only and dual-fuel vehicles, and consumer education. These measures provided ethanol producers and vehicle manufacturers consistency and time to adapt.

Today, Brazil has a large share of the ethanol market and is the world's largest exporter and the second largest producer behind the United States. In response to rising prices in 2010, the government implemented a temporary reduction in the fuel-blending minimum, but the minimum is expected to return to 25 percent in June 2013.

CALIFORNIA: BUILDING ENERGY EFFICIENCY

CALIFORNIA REPUBLIC

California's Title 24 building standards code is on the leading

edge of energy efficiency standards[9] and serves as a model for codes in many other jurisdictions. It uses self-ratcheting and performance-based standards to drive innovation in the energy-efficient building industry, and the 2014 code update will make California's standards among the most efficient in the United States and the world.

An independent panel of engineers decides net present value and payback periods for new efficiency technologies, and any technology with a payback of 7 years or less is included in the next code update. Builders are given 3 years to adopt the newly included technology. This system offers consistency and time to adapt for both builders and technology developers.

Performance-based standards allow flexibility in implementing the code. Builders can either adopt designated technologies or show, using government-approved models, the equivalent performance of alternative technologies. This performance-based compliance option motivates innovation and adoption.

Two other government mechanisms support the building efficiency sector. Appliance efficiency standards and more stringent voluntary standards for buildings stimulate some technology advances. The second mechanism, a "public goods fee" on utility bills, funds efficiency programs and updates to the code. This reliable funding source ensures the continuation of efficiency efforts and consistency for the industry.

Due to the Title 24 building standards codes and similar energy efficiency measures, California has the second-lowest per capita energy consumption in the United States. Furthermore, this per capita energy consumption has remained stable over several decades while per capita consumption elsewhere in the United States increased substantially.

DENMARK: WIND

Denmark has developed a successful wind industry through focused investment along the innovation chain. In the 1980s, Denmark's government, recognizing the need for greater energy independence and lower GHG emissions, began a coordinated push to establish and grow a wind energy industry.

[9] Climate differences complicate comparisons of codes, but California's standards are cited widely as a model of efficacy and stringency.

The push began with investment in R&D and the establishment of testing centres for new technologies, which pushed innovations from the laboratories into commercially ready products. Clear technology standards ensured the quality of manufactured products, which allowed interchangeability of parts and supported the eventual export of Denmark's product. The government also created financial support mechanisms to make wind power economical while it developed; these included subsidies that decreased over time, a carbon tax, and a FIT that also guaranteed connection to the transmission grid.

The combination of regulations and financial support caused short-term economic pain with higher energy prices but created long-term benefits, such as reduced regulatory risk and a stable demand for wind power. These benefits matured the wind industry and encouraged investment, including from Danish pension funds. Today, Denmark is energy independent and holds a 40 percent market share in the wind turbine industry.

EUROPEAN UNION: WASTE TO ENERGY

In recent years, the European Union took aggressive steps to develop its waste-to-energy capacity, focusing on standards and regulations. The European Parliament approved a gradual phase-out of landfills by 2025, a target that will be met using stronger recycling requirements and waste incineration. Electricity produced in certain areas qualifies as a renewable energy, therefore contributing to GHG reduction and renewables targets, and many plants provide both electricity and heat, usually at lower prices than alternative sources. Additionally, stringent emissions standards make WTE plants more publicly acceptable, even though actual emissions are frequently well below the standards.

Today, the European Union is second only to Japan in WTE capacity.[10] Since 1995, the percentage of waste incinerated in the EU has grown from 15 to 22 percent, which is behind Japan's 70 percent but is expected to grow rapidly in the next decade.

FINLAND: CLEAN ENERGY

[10] Denmark, the Netherlands, and Sweden have the highest WTE capacity per capita in the European Union.

Similar to Denmark's choice of short-term pain in exchange for the long-term benefit of a robust wind industry, Finland invested in developing its own renewables industry.

The government's involvement is most prominent in funding and financial mechanisms. It maintains several research centres with mandates to coordinate and fund research; these institutions include VTT Technical Research Centre of Finland, Academy of Finland, and Tekes, the Finnish Funding Agency for Technology and Innovation. Additional government organizations, such as the Finnish Innovation Fund (SITRA) and the Vigo Program, develop systematic strategies for promoting innovation in target industries and provide risk capital and mentorship to young companies. Furthermore, VTT maintains foreign energy offices in the San Francisco Bay area and São Paulo, Brazil, to encourage knowledge transfer and establish international links useful for exporters.

Financial mechanisms used by the government focus on capital investment subsidies and tax incentives. FITs or production subsidies were used minimally and only in a few cases to bring energy prices to grid parity.

Today, Finland's electricity mix is dominated by a mix of renewables (31 percent) and nuclear (28 percent). However, Finland still struggles with relatively high per capita carbon emissions and is pursuing policies to bring its renewables share of energy consumption, including transportation, to 38 percent, in line with EU targets.

ISRAEL: EXPORTING

Israel creates significant economic value from selling its goods abroad, exporting high-value-add goods to diverse markets. A small domestic market[11] motivates this exporting, but a variety of government resources support the exporting businesses, particularly through fostering collaboration. For example, the Foreign Ministry sets up representative offices in target markets to introduce Israeli companies to potential trading partners and to offer resources and infrastructure, such as office space and support in navigating immigration laws. Another organization, the Israel Export and International Cooperation Institute (IEICI), was founded collaboratively by the government and private sector and promotes business ties and joint ventures between domestic and

[11] Israel's population is less than 8 million.

foreign companies. Similarly, the America-Israel Chambers of Commerce sponsor trips for US companies and investors to tour Israeli industries, which attract trade and foreign investment.

Today, Israel's exports are worth over $80 billion and have transitioned from low-value-add goods to a limited number of markets into high-value-add goods (24 percent chemicals, 20 percent electronics[12]) to a diverse set of markets (24 percent US, 30 percent EU, 22 percent Asia, 24 percent other[13]).

NETHERLANDS: INDUSTRIAL ENERGY EFFICIENCY [redacted]

The Netherlands has successfully increased industrial energy efficiency using a unique mechanism known as Long Term Agreements (LTAs). LTAs are voluntary compacts between the Ministry of Economic Affairs and industry to reduce energy intensity in operations and feedstock. Government assistance focuses on education and collaboration.

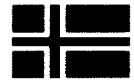
To fulfill the terms of the LTA, companies perform energy efficiency assessments, draw up plans for reduction and estimate expected impact, implement the plans, and monitor and report their progress. New plans are submitted every 4 years, which encourages continual improvement and provides consistency to both companies and the efficiency technology industry. Another requirement, that efficiency measures be economical with payback periods of 5 years or less, also encourages technology improvement and brings economic gains to the LTA partners. A government agency, SenterNovem, provides assistance to companies in creating plans, navigating the LTA policy, and sharing best practices.

Since its inception in the 1990s, the LTA program has signed on over 1,000 companies representing 90 percent of industrial energy consumption. It has also achieved a 20 percent increase in efficiency and yielded financial gains to its industries; the program has accomplished these improvements with minimal direct investment of capital.

12 Includes office equipment and appliances.

13 Excludes destinations of exported diamonds.

NORWAY: OIL AND GAS



When large oil and gas reserves were discovered in Norway in the 1960s, the government identified four key tasks for itself:

1. Establish a long-term vision that aligns with key stakeholders and manifests in proactive adjustments in regulations to maintain a supportive environment.

2. Leverage the experience of international oil companies through a thoughtful resource access policy for frontier exploration.

3. Ensure competition among companies.

4. Support local R&D.

To accomplish these tasks, Norway's government provided coordinated and consistent support to several points along the innovation chain. It invested in R&D while making frequent adjustments in tax policy to incent private sector investment in R&D, exploration, and development. It supported domestic companies, including government-owned Statoil, with a licensing system that required domestic involvement in all oil and gas operations and with an education system that adjusted its curriculum to train locals for industry jobs. Furthermore, the government offered multinational oil and gas companies access to the Norwegian Continental Shelf in exchange for bringing knowledge and technical expertise to domestic companies.

Today, Norway is the world's third largest exporter of oil and seventh largest producer of gas. Its robust oil and gas industry transformed Norway into the third-richest nation per capita and developed Norwegian leadership in certain specialized drilling and extraction techniques.

PORTUGAL: ELECTRIC VEHICLES

Despite a weak economy and austerity mandates, Portugal has maintained its investment in electric vehicle infrastructure, adoption incentives, and public-private partnerships in the hope of developing a robust electric vehicle industry with high penetration rates.

A public-private collaboration project, Mobi.E, is building nationwide charging infrastructure with an emphasis on accessibility to all EV brands and streamlined payment. To increase the availability of EVs to consumers, Portugal signed an agreement with Renault-Nissan to sell its Leaf earlier than in other countries and

to establish a battery manufacturing centre. Incentives to consumers include exemption from the ownership tax on vehicles and additional tax breaks for the purchase of an EV or the retirement of a conventional vehicle. Furthermore, the government procured 8 Leafs for the police force and proposed a labeling system with vehicle efficiency information.

Today, the Mobi.E project has installed 1,300 charging stations, and Portugal has the lowest average emissions in Europe for its new vehicle fleet. Consumer adoption has been slower than expected, and the country is off track to meet its goal of 10 percent EVs by 2020. The government believes that the lack of consumer information about lifetime vehicle costs is contributing to the sluggish adoption and hopes the proposed labeling system will stimulate demand.

SINGAPORE: WATER

Despite limited natural resources, Singapore has become increasingly water-efficient due to the government's holistic and coordinated approach to management. A concept of "Four Taps", which should be used in a balanced portfolio, captures the overall goal of greater water independence; the Four Taps are local water catchments, imports, reclaimed water, and desalination. Three government agencies play the largest roles in water management – the Ministry of the Environment and Water Resources (MEWR), the Public Utilities Board (PUB), and the National Environment Agency (NEA) – and they use a variety of levers targeted at multiple points in the innovation chain.

Singapore's government funds R&D and infrastructure for both desalination and a leading-edge project in reclaimed water, called NEWater, that feeds into industrial uses and drinking supplies. The Environment and Water Industry Development Council was established to support the development of Singapore as a water research hub, including attracting foreign and private sector investment.

Other measures protect existing supplies, including careful land management around reservoirs and adjusted pricing that removes subsidies and reflects the full cost of supplying water, thus encouraging conservation.

Because of its aggressive and coordinated efforts, Singapore is on track to become water-independent. Some of its water agreements with Malaysia expired without being renewed given Singapore's lower needs, and the government hopes to allow later agreements to expire without renewal as well. Today, reclaimed

water provides 30 percent of demand, and desalination supplies 10 percent; these numbers are expected to grow to 50 percent and 30 percent, respectively, within the next few decades.

TAIWAN: SEMICONDUCTORS

Taiwan has developed a semiconductor innovation and export hub, guided by government action that followed three important principles: synchrony with a long-term vision; careful timing of the action, including the government's exit when appropriate; and policy coordination across the value chain.

In the 1980s, Taiwan's government identified electronics as a promising emergent industry, and established the Electronics Research and Service Organization (ERSO) to lead the development of industries, including allocating targeted funding to R&D needs. ERSO was strongly connected with another organization, the Industrial Technology Research Institute (ITRI), which focused on performing R&D, fostering collaboration between industry and research, and facilitating technology transfer from developed nations to the domestic industry.

In addition to these organizations devoted to industry and research development, the government funded research centres at multiple universities to promote greater involvement of academia and encourage talented students to develop skills in electronics. Furthermore, the government devoted an agency to attracting foreign and expatriate talent, which used incentives such as streamlining immigration and raising the salary cap on foreign employees in government-funded organizations.

As ERSO and ITRI work progressed, the government supported the domestic industry's maturation with tax incentives, access to knowledge and R&D funding, low-cost loans, and employee benefits such as housing and medical care. Additionally, two foundries were spun off from ITRI and privatized – United Microelectronics Corporation (UMC) and Taiwan Semiconductor Manufacturing Company (TSMC). Today, Taiwanese firms, mostly UMC and TSMC, hold over 60 percent market share in semiconductors.

UNITED STATES: SHALE GAS

Today's shale gas boom in the United States was driven in part by government support that started in the 1970s and was available at every stage of the commercialization value chain.

Government-funded research produced necessary equipment and processes for drilling and extraction. When the technology was ready, public-private partnerships demonstrated commercial-scale operations, and a production tax credit lasting nearly 20 years incented production before it was independently economical.

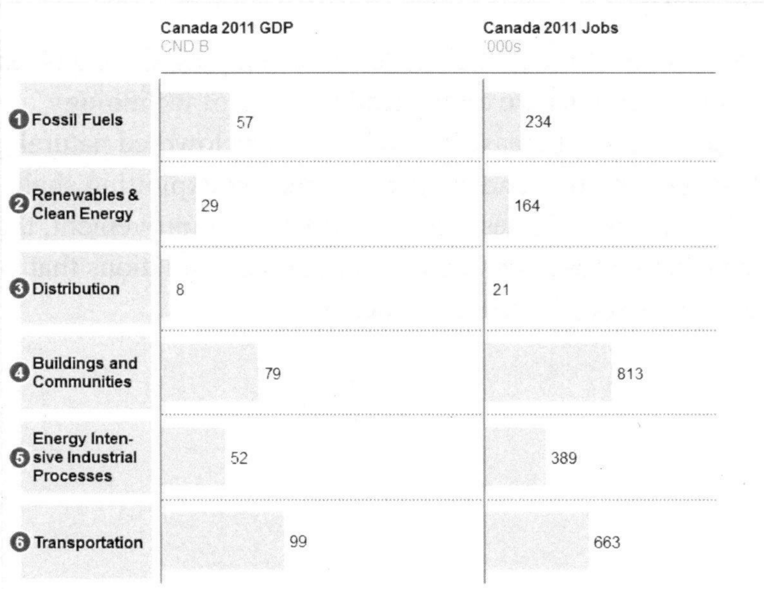
Regulations also create a secure environment for developing the industry. Mineral-rights law gives landowners, rather than government, consistent rights to resources, encouraging exploration and exploitation of resources. Regulations on operations are generally transparent and standardized, although there is some variation among states.

Today, the United States is the global leader in developing shale gas resources – US companies and operations are on the leading edge of technology development, and the rapid increase in production has lowered natural gas prices, thus encouraging consumption and spurring interest in exploiting shale gas resources outside the United States. There is room for improvement, though, especially in remediation research and environmental regulations that will maintain the industry's social licence to operate.

Appendix: GDP/Jobs Economic Impact Model

An economic impact model (EIM) was built to describe the impacts of a government strategy that prioritized greater energy technology focus. This model allowed estimation of increases in GDP output and job growth for the 2020 time frame. Sector-specific contributions for GDP and jobs were used, with initial values broken down from NRCan data into the six energy-related sectors (fossil fuels, renewables and clean Energy, distribution, buildings and communities, energy-intensive industrial processes, and transportation), each with 2011 values for GDP and Canadian jobs, shown in Exhibit 47 (note that these figures are denominated in 2002 dollars).

EXHIBIT 45



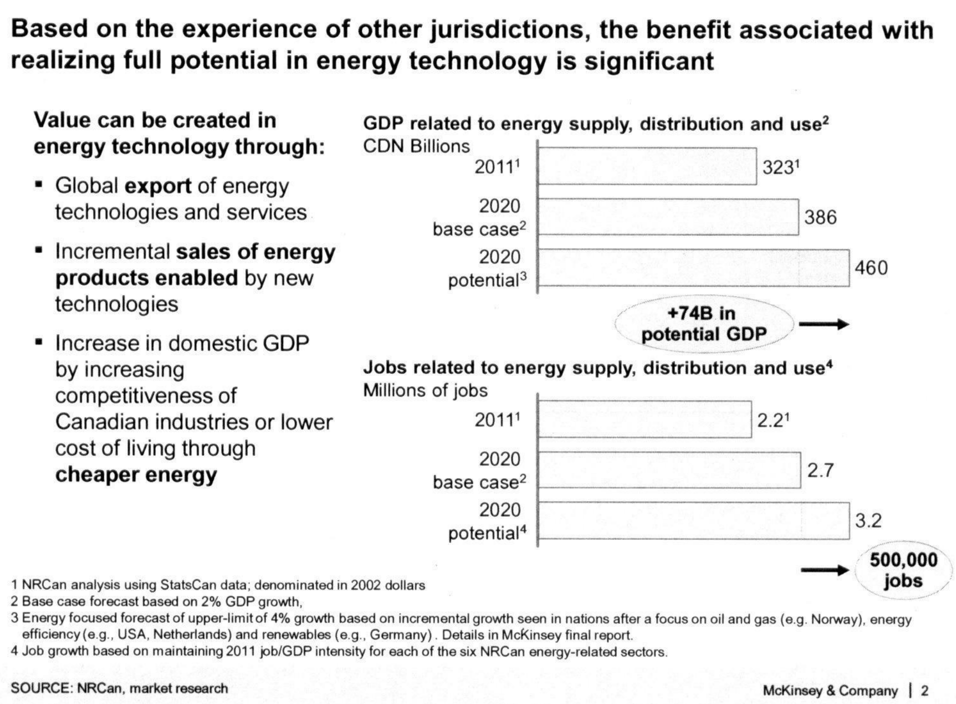
SOURCE: Statistics Canada, 2011 (socio-economic data includes supply industries for each of the 6 sub-categories); NRCan

The EIM assumed a baseline GDP annual growth rate (real) of 2.0 percent through to 2020, based on IHS Global Insight forecasting (see Appendix: GEP Model Assumptions). Prior McKinsey analysis on economic impact of energy-focused policies in other jurisdictions showed a maximum contribution of 2.0 percent (e.g., Norway compared to non-oil Scandinavian nations, energy efficiency policies in California compared to states without these policies) to real

GDP growth rate in a 10-year period, which would bring the maximum real GDP growth rate to 4.0 percent within the energy-related sectors, inclusive within the 2020 time frame. Growth rates were used instead of absolute contribution to GDP to normalize for different economy sizes.

The maximum impact on real GDP in the year 2020 would then occur if the 4 percent growth rate were applied across all sectors, suggesting a maximum of $74 billion in additional real GDP (including direct and indirect) by the year 2020. Maximum job growth was calculated assuming a constant 2011 jobs/GDP intensity for each of the energy-related sectors, (e.g., using the 2011 fossil fuels jobs/GDP intensity of 4.12 jobs/$ million GDP for 2020). This led to a net benefit of approximately 500,000 new energy-related jobs, shown in Exhibit 48.

EXHIBIT 46



While the EIM model here does not get to the level of granularity to distinguish between growth rates among sectors, nor include the effects of current policies in Canada, the proxy of using an aggregate GDP growth rate across sectors serves to indicate and compare the absolute size of growth in GDP and jobs across sectors, knowing that, for example, fossil fuel GDP growth may be higher than 2 percent,

and distribution might be less. However, the 4 percent GDP growth would be well-placed across sectors, spreading risk and, in some cases, creating a higher absolute number of jobs (e.g., buildings and communities). Exhibit 49 shows the breakup of individual sectors based on the 4 percent GDP growth rate scenario across all sectors.

EXHIBIT 47

Opportunities for Canadian energy technologies in global markets

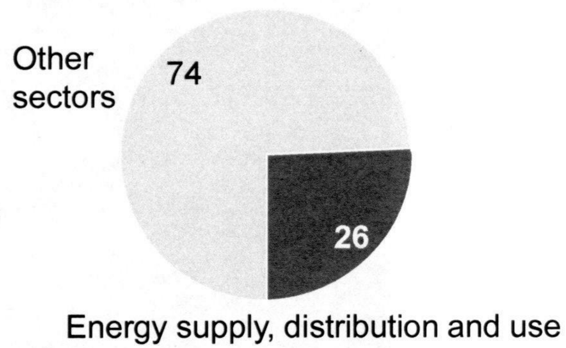
Cat. No. M34-19/2013E-PDF (Online)
ISBN 978-1-100-22652-1

This analysis was commissioned by Natural Resources Canada, and performed by McKinsey & Co. It does not necessarily represent the views of the Government of Canada.

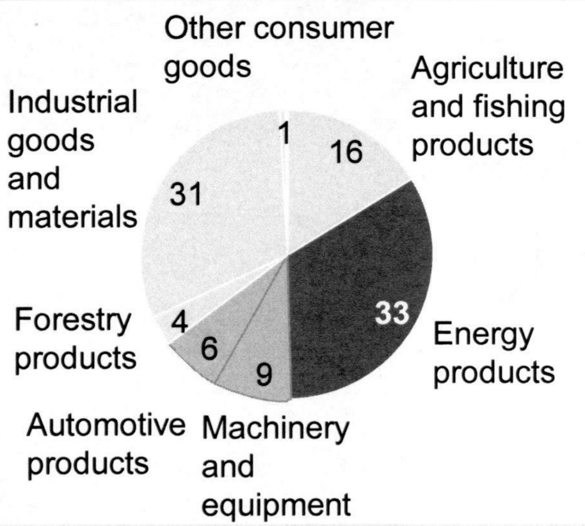
The successful development and exploitation of energy technology is critical to the future of the Canadian economy

Energy is vitally important to the Canadian economy

Contribution to Gross Domestic Product (GDP) %



Contribution to trade balance



Canada has some strong advantages related to energy relative to other jurisdictions

Rank	Endowment
5th	Primary energy production – 19.1 quadrillion British thermal units (QBTU)
3rd	Crude oil reserves – 175.1 billion barrels
21th	Natural gas reserves – 61.9 trillion cubic feet
11th	Coal reserves – 6,582 million tonnes
3rd	Uranium reserves – 485,000 tonnes
7th	Electricity generation capacity – 127.64 gigawatts (GW)
6th	Electricity generation – 632.3 terawatts-hours (TWh)
19th	Fossil fuels – 152.71 terawatt-hours
7th	Nuclear – 85.9 terawatt-hours
3rd	Hydro – 363.2 terawatt-hours
13th	Wind – 3.6 terawatt-hours
9th	Biomass – 7.6 terawatt-hours

Energy technologies are poised to be disruptive at all stages of the energy value chain

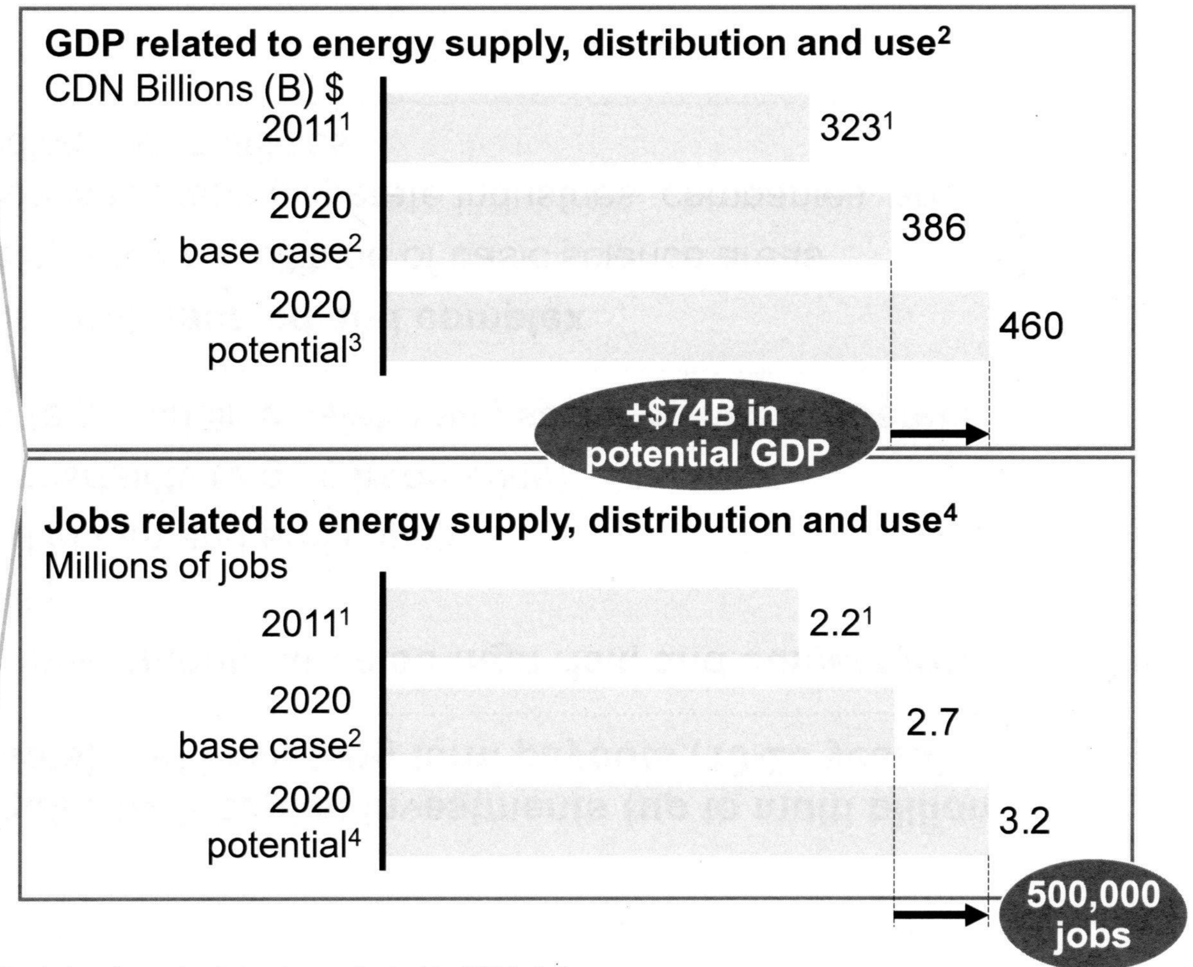
- **Energy supply:** new oil and gas extraction technologies creating access to previously inaccessible resources, renewables rapidly declining in cost and starting to reach grid parity
- **Energy distribution:** smart grid technologies will integrate renewables and help monitor/ reduce energy usage
- **Energy demand:** energy efficient technologies are shaping industrial and commercial sectors in anticipation of emission regulations, fuel efficiency regulations are driving innovations in transportation

SOURCE: Statistics Canada, Centre for Energy, McKinsey Electric Power and Natural Gas (EPNG) and Sustainability and Resource Productivity (SRP) Practices

Based on the experience of other jurisdictions, realizing the full potential of energy technology can drive GDP and job growth

Value can be created in energy technology through:

- Global **export** of energy technologies and services
- Incremental **sales of energy products enabled** by new technologies
- Increase in domestic GDP by increasing competitiveness of Canadian industries or lower cost of living through **cheaper energy**



1 Natural Resources Canada (NRCan) analysis using Statistics Canada data; denominated in 2002 dollars
2 Base case forecast based on 2% GDP growth,
3 Energy focused forecast of upper-limit of 4% growth based on incremental growth seen in nations after a focus on oil and gas (e.g. Norway), energy efficiency (e.g., United States (US), Netherlands) and renewables (e.g., Germany).
4 Job growth based on maintaining 2011 job/GDP intensity for each of the six NRCan energy-related sectors.

SOURCE: NRCan, market research

Yet there are a number of unique characteristics and challenges related to the development of energy technologies

- **Energy projects require high capital investments (up to multi billion dollars for major pilots) and have long term payouts (10-20 years)**

- **Energy technology investments are also high risk, and subject to:**
  - Energy price volatility
  - Shifts in global market demand and supply
  - Policy regulatory uncertainty (e.g., carbon price)
  - Environmental risk (e.g., pipeline safety) and social license to operate

- **The energy sector is multi-faceted and complex**
  - Technologies develop from a multitude of basic science areas
  - The sector encompasses many disparate industries, companies, and stakeholders including public utilities

How Canadian governments can create and sustain advantage in energy technologies

Create an enabling environment that supports energy technology

- Ensure access to markets
- Ensure access to capital
- Ensure access to talent/capacity
- Ensure effective coordination of government institutions/bodies

Provide targeted support to maximize potential in priority technology areas

- Understand where Canadian firms have the potential to be an international leader – and be clear on trade-offs being made
- Drill-down to identify those barriers facing priority technology areas which government is uniquely positioned to resolve – don't focus on barriers the market is able to solve
- Support priority sectors using a combination of financial, policy, and facilitation levers

In response to the unique challenges facing Canada, there are four things Canadian governments can do to create a more enabling environment

DETAILS ON NEXT SLIDE

	Specific challenges facing Canada	Potential government actions to build an enabling environment
Access to markets	Export market is particularly important for Canada: ▪ Canada has a relatively small domestic market (compared to the US or China) ▪ Inexpensive power drives GDP in Canada, but means that emerging energy technologies are less competitive, and may take longer to be cost competitive here than in some other countries	Create stronger domestic demand through policy and provide additional support to companies exporting to emerging (e.g., Asia, Africa) and competitive (e.g., US, European Union (EU) markets
Access to capital	Scarcity of private funding and a poorly performing venture capital market	Help coordinate provincial and federal financing vehicles (e.g., venture capital (VC), government "prizes") to address a broader range of opportunities
Access to talent	Shortage of skilled labour in key areas (e.g., oil sands operators, power plant engineers); loss of entrepreneurial talent to US market	Cultivate domestic talent and ensure access to international sources as required
Coordination of institutions	Less government action in energy space relative to other countries at the federal level; opportunity to work in a more focused and disciplined way to achieve the same results as other jurisdictions	Create a highly coordinated network of government institutions, such as research centres and startup incubators, to support technology developers along the entire innovation funnel

In response to the unique challenges facing Canada, there are four things Canadian governments could do to create a more enabling environment

	Example actions
1. Create stronger domestic demand through policy and provide additional support for companies exporting to price competitive markets	▪ Use policy to ensure stable, robust domestic demand in target energy sectors and consequently spur industry innovation (e.g. standards like California's building efficiency codes, incentives like the US's shale gas production tax credit) Provide a range of export assistance: ▪ Provide assistance in navigating international intellectual property (IP) law ▪ Help connect small companies with international customers to enable set-up of demonstration projects (e.g., Israel's exports) ▪ Facilitate visits of foreign stakeholders to tour Canadian industry ▪ Enhance domestic resources to help companies prepare strategies for export (e.g. networks to connect participants that form export supply chains)
2. Help coordinate provincial and federal financing vehicles (e.g., VC, government "prizes") to address a broader range of opportunities	▪ Encourage collaboration and risk-sharing between regional and federal capital (e.g., federal support when regional VCs or universities find a promising technology investment) ▪ Explore options to reduce premature technology sales for raising capital, e.g., – Provide alternate sources of capital so that entrepreneurs do not feel unduly pressured to seek short-term profit by selling IP – Place restrictions on VC funds to keep IP in Canada until sustainable business is built ▪ Offer cash or in-kind "prizes" as rewards to technology developers that take risks, ensuring targeted spending when technology progress occurs
3. Cultivate domestic talent and ensure access to international sources as required	▪ Create vocational/educational programs that serve energy technology developers (e.g., Norway's oil and gas) ▪ Ensure that developers are able to import skills (e.g., Taiwan's semiconductors) ▪ Develop culture of technology entrepreneurism, give best entrepreneurs reasons to stay
4. Create a highly coordinated network of government institutions, such as research centres and startup incubators, to support technology developers along the entire innovation funnel	Ensure that this network is collectively able to: ▪ Coordinate research, development and deployment (RD&D) with standards/regulations policy programs (e.g., Singapore's water) ▪ Ensure government institutions are integrated with industry and set-up to utilize co-funding programs and seed risk capital; particularly help small and medium enterprises (SMEs) who are most challenged in accessing capital (e.g., Finland's Innovation Fund, SITRA) ▪ Take direct role in commercialization of new technologies through public-private partnerships (e.g., Taiwan's semiconductors)

SOURCE: Expert, industry, and government interviews; market reports, McKinsey EPNG and SRP Practices
See Appendix for case studies of successful actions in each of the four recommendation areas

Decisions on where to focus targeted support should be grounded in an understanding of the global energy outlook through 2030

Fossil fuels remain important as an energy source through 2030:

- New technology development allows access to previously inaccessible unconventional resources (e.g. oil sands in Canada, shale gas in US)
- Coal remains an important resource in Asia

Renewables are a small, but increasingly important power source by 2030:

- Technologies are maturing and coming down the cost curve quickly, making them competitive in select geographies (e.g., solar for peak generation in sunny climates, wind for offshore areas and islands)
- While installed base is mostly fossil fuels, forward capital expenditure (capex) growth is heavily renewables
- Adoption is also driven by emissions related targets and anticipation of increased regulations
- Adoption in Canada of new renewable technologies (solar, wind, biomass) will be slower than other geographies due to existing hydro and nuclear power generation capacity

Demand for energy is driven by new middle class, but offset partly by efficient technologies:

- Emergence of 3 billion middle class in Asia driving increased demand for cars, buildings and other consumers products
- Demand increase is partly offset by stricter fuel efficiency standards (which in turn has driven innovation in fuel-efficient transportation, with Plug-in Hybrid Electric Vehicles (PHEV) adoption likely by 2030), causing slight decrease in fuel demand in Canada and US
- Demand is also reduced by development and adoption of energy efficient technologies for both buildings and industrials, particularly in developed economie

See Appendix for data charts

SOURCE: McKinsey Global Energy Perspective Model, McKinsey Resource Revolutions Report, McKinsey EPNG and SRP Practices

Based on this global forecast fourteen technology areas are poised to have significant market pull by 2020 (1/2)

	Technology area	Technologies under consideration	Market size and drivers
Fossil fuels	**Unconven-tional gas**	Shale gas extraction, supply chain and field management, gas to liquid and liquefied natural gas (LNG), environmental technologies	Unconventional gas will be 30% of North American gas production by 2020 due to improved extraction technology, causing flat natural gas prices
	Unconven-tional oil	Bitumen extraction, upgrade, environmental technologies, pipelines	~$100B market in 2020 for oil sands ($20B in capital expenditure and ~$80B in revenue) due to improved extraction techniques and rising conventional oil prices (Unconventional oil only attractive at high oil prices, which are expected to continue)
Renewable and Clean Energy	**Solar Photo-voltaic (PV)**	Poly-Silicon to PV module value chain, balance of system, end applications, concentrated solar power (CSP)	PV modules market $325B worldwide by 2020, $962B by 2030 driven by decreases in PV module price and new applications
	Wind	Wind Turbine Generator (WTG) components, manufacturing and operation	WTG market $680B by 2020, increases in reliability, efficiency and cost-effectiveness driving worldwide adoption
	Bioenergy	Biomass collection and processing, bioheat, biopower, combined heat and power (CHP)	$100-200B potential in capital expenditure in 2020, mostly in EU markets driven by regulatory requirements
	Biofuels /Biorefinery	Production of biodiesel, bioethanol, other 2nd generation biofuels and biorefinery products	64 gigaliters (GL) cellulosic biofuel demand in 2020, with 400 new plants built for cellulosic biofuels. Markets driven by regulations, subsidies, strategic considerations (e.g. bio-jet fuels) and low cost of 1st generation bio-ethanol.

SOURCE: McKinsey Global Energy Perspective Model, market research, expert interviews

Based on this global forecast fourteen technology areas are poised to have significant market pull by 2020 (2/2)

	Technology area	Technologies under consideration	Market size and drivers
Distribution	**Smart Grid**	Metering, grid storage, network, demand management/response, appliances, software and integration, transmission & distribution (T&D) components, renewables integration	$41B in 2011 for hardware and software, growth driven by increased utility adoption $10B by 2020 in T&D components driven by utility adoption of more efficient, reliable, and controllable power electronic components
Buildings and Communities	**Energy Efficient (EE) Buildings**	Advanced windows value chain, heating and cooling value chain, system integration, prefab houses	30% of energy use today, large 2011 market for windows ($69B) and heating and cooling ($130B), strict regulations will drive new construction and refits to higher efficiency
	Advanced lighting	Light emitting diode (LED) lighting (semiconductor, packaging, luminaire, control)	$38B LED lighting market by 2020, driven by banning of incandescents and decrease in cost of LEDs
Energy intensive industrial processes	**Waste to energy (WTE)**	Equipment, design and engineering, construction	$4B in revenue, $77B equipment market in 2014, EU markets driven by tipping fees
	Water	Water treatment equipment, operation and maintenance, consumer and commercial products	$515B global market in 2011 ($110B for equipment), increasing pressure on water supplies driven by both population and industrial/mining/extraction demand
	EE Industrial	Industrial process optimization	32% of energy use today, disruptive processes can save up to 50% of energy use and reduce emissions
Transportation	**Compressed natural gas (CNG)/LNG fleets**	Natural gas (NG) engines and refueling infrastructure	Long term compressed natural gas/liquid natural gas heavy vehicle adoption in North America (NA) (1/5 of heavy vehicles by 2020) spurred by low NG prices
	Next generation (Next-gen) auto	Internal combustion engine (ICE) technology, regenerative braking, lightweighting, batteries, motors, charging infrastructure	22M plug-in hybrid electric vehicles (PHEV) /year by 2020, 87M by 2050 with increasing battery electric vehicle (EV) adoption in China

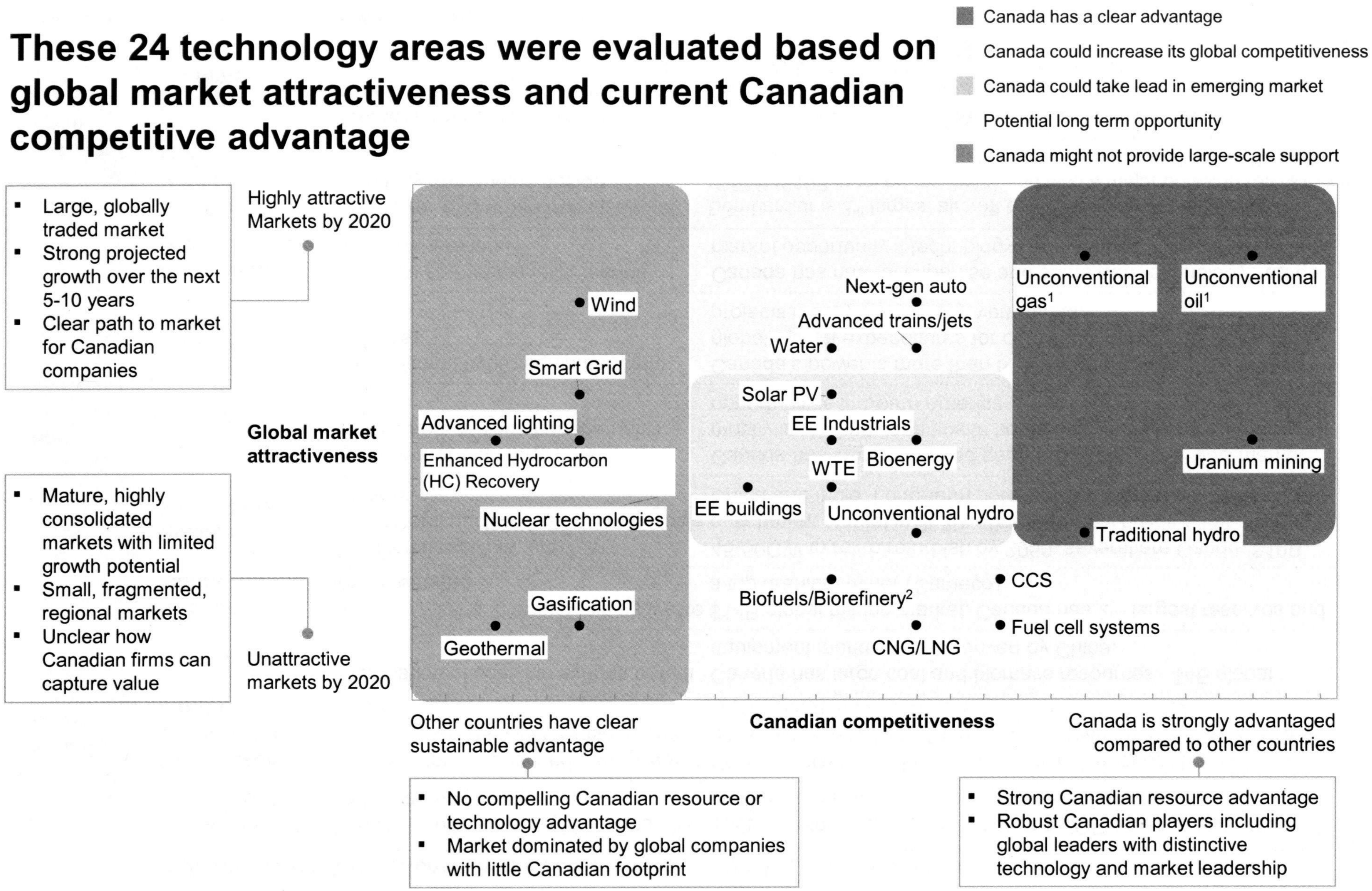
SOURCE: McKinsey Global Energy Perspective Model, market research, expert interviews

Ten additional technology areas were considered based on their strategic importance to Canada and their link to our resources

	Technology area	Technologies under consideration	Market size and drivers
Fossil fuels	Enhanced HC Recovery	Enhanced oil recovery (EOR) and coal bed-methane (CBM)	$36B market in 2011 from Canada's EOR revenue and global capital expenditures, driven by higher oil prices
	CCS: Carbon capture and storage	Carbon capture, coal and natural gas (NG) CCS builds, CO2 transport and storage	CCS for offsetting oil sands CO_2 cost. Dependent on CO_2 price acceptance in EU and China; slow growth until 2030+, $230B in capital expenditures on gas and coal CCS in 2050
	Gasification	Gasification of coal into syngas or fuel	Canada has large coal and biomass resources. $4B global equipment market, mostly driven by China.
Renew-able energy sources	Uranium mining	Uranium mining, uranium mining waste management	$14B global mining market, Canada has 2nd largest reserves and a top uranium miner (Cameco)
	Nuclear technologies	Traditional reactors, uranium enrichment, nuclear fusion, small-scale reactors	45-50GW to retire/refurbish by 2050, several are Candu; $10B enrichment market in 2020; 400-500B new builds primarily in China and India. Long-term potential in fusion and small-scale.
	Geothermal	Power generation (equipment, engineering, project management), CHP	Canada has large untapped geothermal potential. $3B market mostly in US and Japan (with some delays in Onsen), some opportunities in South America.
	Traditional Hydro	Conventional hydro equipment and services	Canada's power is more than 50% hydro through 2050. $420B global capital expenditures for conventional hydro in 2020, large projects mostly driven by governments.
	Unconventional Hydro	Run of river, hydrokinetic, marine power generation	Canada has natural expertise and some new technology. Large market opportunity if technology is developed.
Transport ation	Advanced trains and aircraft	Electric rail and urban transit, aircraft assembly and engine design	Bombardier is 3rd largest aircraft original equipment manufacturer (OEM) ($10B in revenues 2011) and also a major player in rail ($10B in revenues 2011). Attracts international suppliers and domestic growth.
	Fuel cell systems	Hydrogen fuel cells, charging infrastructure, fuel cells in grid storage	Canada has significant investments in hydrogen fuel cell development. Large potential beyond 2020-2030 depending on fuel regulations and technology cost reduction

SOURCE: McKinsey Global Energy Perspective Model, market research, expert interviews

These 24 technology areas were evaluated based on global market attractiveness and current Canadian competitive advantage



1 Global capex and sales from Canadian oil or gas only
2 Global capex and sales from cellulosic biofuels only (includes agriculture waste)

SOURCE: McKinsey Global Energy Perspective Model, market research, expert interviews

In some instances, governments are uniquely positioned to address barriers to Canadian technology competitiveness

In many energy technology areas, market forces are eroding barriers effectively; for example, industry players are:

- Investing in research, development, and demonstration (e.g., cost reduction in oil sands extraction, development of some next-generation transportation components)
- Overcoming market structural challenges with appropriate business models and forming partnership/consortiums (e.g., energy audit firms working with technology companies and clients to help with adoption of energy efficient technologies)

However, when market forces fail to remove barriers, government intervention is warranted:

- Assisting energy companies to overcome the “valleys of death” in the commercialization lifecycle which are driven by:
  - The high technical risk associated with demonstrating the applied worth of technologies, leading to technologies dying at the "basic science" stage
  - Long time to market, making it difficult to attract industry funding for demonstration and pilots
  - The high capital costs which prevent industry from investing to move technology along “learning curve”
- Fostering market conditions that are needed to stimulate demand:
  - Lack of global demand for technologies due to negative customer perception that is not well addressed through market mechanisms
  - Structural barriers due multi-party complexities (e.g., renters benefit from EE heating ventilation and air conditioning (HVAC), but owners pay for the HVAC unit; new waste to energy plant with better technology cannot access waste stream because waste utilities are not incentivized to change)
  - “Chicken and egg” issue between infrastructure investment and adoption of a particular energy technology (e.g., electric vehicles)

SOURCE: US National Institute of Standards and Technology (NIST), expert interviews

There are six categories of levers that government can use to help remove the barriers to improving Canadian technology competitiveness

	Examples
Direct investment	▪ Government labs; grants for research, development, and demonstration; provision of risk capital for technology commercialization ▪ Provision of capital for pilots or deployment, including procurement (e.g., piloting leading-edge efficiency tech in government buildings)
Incentives & financing	▪ Low-interest loans to stimulate demand for technology adoption ▪ Tariffs or tax breaks related to technology adoption
Infrastructure investment	▪ Physical infrastructure investments to enable specific industries (e.g., charging stations for EV)
Standards and regulations	▪ Performance standards, potentially with disincentives ▪ Licenses & permits ▪ IP protection laws
Education and information	▪ Providing monitoring data to end users ▪ Consumer labeling (e.g., Energy Star) ▪ Investments in labor capabilities and capacity to enable an industry (e.g., building education capacity for researchers and field workers)
Foster collaboration	▪ Establishment of national vision and strategy ▪ Network building and connection of stakeholders ▪ Multi-lateral offerings (e.g., utility-funded installation of home energy efficiency tech by private company)

Five natural "clusters" of opportunity for government to intervene to maximize opportunities in energy technologies

DETAILS ON FOLLOWING PAGES

Cluster	Technology areas	Cluster assessment
1 Unconventional oil and gas	▪ Unconventional oil ▪ Unconventional gas	▪ Industry players are already investing heavily in technology RD&D and commercialization of oil and gas technologies ▪ Canadian government can sustain advantage by fostering collaboration around environmental technologies to enable the social license to operate
2 Next generation transportation	▪ Next-gen auto ▪ CNG/LNG	▪ Industry players are already investing heavily in RD&D and commercialization of EV or PHEV components in anticipation of fuel efficiency standards ▪ Canadian government can be a leader in regulations and standards, and selectively invest in best-in-class technologies to ensure Canada continues to be a manufacturing hub and build exportable infrastructure capabilities
3 Energy-efficiency technologies	▪ EE buildings ▪ EE industrials ▪ Water	▪ Market is already making some investments on technology development, but both adoption and development are slow due to structural challenges ▪ Canadian governments can drive innovation through education, incentives for early adoption and/or progressively tightening regulatory standards
4 Distributed power generation	▪ Unconventional hydro ▪ Bioenergy ▪ Waste to energy ▪ Solar	▪ Fast growth and emerging market, Canada is one of multiple countries with technology development, but high levels of competition ▪ Canadian governments can drive global competitiveness by selectively deploying the most appropriate levers (described on slide 18) based on benchmarking specific Canadian technologies to global competition
5 Potential longer term opportunities	▪ CCS ▪ Fuel cell systems ▪ Biorefineries and biofuels	▪ Markets are potentially attractive, but outlook and timing depends strongly on either major regulatory shifts or technology breakthrough ▪ Postpone further large-scale government support until key developments or major industry investment decrease the level of commercialization risk ▪ Offer "prizes" as incentives for faster development as low-risk option
Market forces are effective	▪ Traditional hydro ▪ Uranium mining ▪ Advanced trains/jets	▪ Market leaders and technologies are established ▪ Since private industry is investing to remove market barriers (e.g., technology, cost barriers), there is limited need for government actions

1 Canadian governments could sustain advantage on unconventional oil and gas

Technology area	Description of barrier	Highest potential levers	Rationale including international examples
▪ Unconventional oil and gas: water treatment, air quality and land remediation	▪ New environmental tech exists at small scales, but need to be proven with pilots ▪ Industry usually stalls full-scale pilots until regulations are mandated and enforced ▪ Despite short-term increased costs, phased standards often encourages development of new environmental technologies at attractive long-term economics and global competitiveness	▪ **Foster collaboration** across potentially competitive companies to facilitate tech transfer of environmental technologies across industries (e.g., a research centre, or consortiums) ▪ Consider **regulation/standards** to spur domestic innovation in the long term ▪ **Incentivize** private sector firms (e.g. reduced Provincial royalties, risk-sharing, government prizes for solutions to solve technological challenges)	▪ Improving performance of environmental technologies is essential for social license to operate and for broad exportability (e.g., certain regions have banned shale gas) ▪ Consortiums can help reduce cost base across industrial players ▪ Phased regulations have proven successful in spurring innovation, and if Canadian governments are more aggressive than other jurisdictions in these regulations, it could ensure long term competitiveness of Canadian technologies (e.g. building efficiency in California, water in Singapore) ▪ Once developed, the environmental technologies can be exported to other regions or industries
▪ Unconventional oil: drilling and extraction technologies	▪ Lowering costs of drilling and extraction is important to maintain advantage through tapping into currently uneconomic resources: – To show viability of a new in-situ extraction technique, it must be piloted at full-scale – Operators face a trade-off of piloting new techniques vs. immediate production	▪ **Foster collaboration** between technology holders and oil majors, help form consortium between oil majors ▪ **Incentivize** private sector firms (e.g. reduced royalties, risk-sharing, government prizes for solutions to solve tech challenges)	▪ Oil companies are currently investing in developing the technology through pilots, but Canadian governments can help accelerate this process through incentives (e.g., shale gas in the US) and enabling connections between industry players (e.g., oil and gas sector development in Norway)

SOURCE: Expert, industry, and government interviews; market reports; McKinsey EPNG and SRP Practices

2 Canadian governments could cultivate Canadian leadership in next generation transport

Technology area	Description of barrier	Highest potential levers	Rationale including international examples
▪ Next-gen auto: accelerate PHEV adoption through lowering costs	▪ While industry is already investing in batteries, advanced internal combustion engines (ICEs) and lightweight vehicles, speed of adoption is dependent on lowering costs through achieving scale	▪ **Regulations and standards** for fuel efficiency to lead US/EU ▪ **Incentivize** auto suppliers to build-up supply chain in Canada	▪ If Canada sets fuel efficiency regulations that are more advanced and aggressive than the US/EU, it can cement Canada's role as a pilot site for new technologies (e.g. building efficiency in California)
▪ Next-gen auto: PHEV infrastructure	▪ Uncertainty in charging standards, uncertain technological advancement and competition among manufacturers has slowed adoption of PHEV ▪ Manufacturers are deferring infrastructure investment until demand is greater	▪ **Infrastructure investment** – either directly or in coordination with private sector firms ▪ **Foster collaboration** to drive adoption of a unified charging standard and enable innovation and export of Canadian infrastructure technologies/services	▪ Canada could be an early leader in infrastructure, attracting foreign investment for pilots and then develop innovation and export capabilities
▪ Next-gen auto: inexpensive electric motors	▪ Rare-earth magnets are a critical cost component for electric motors ▪ China has established a low-cost rare-earth supply, stifling rare-earth mining investments in other countries – China has thus become global leader of e-motor manufacturing and technology, vehicle OEMs are concerned over lack of competition	▪ **Infrastructure investment** in creating a rare earth supply in Canada ▪ **Incentivize** OEMs to be present and participate in an e-motor hub in Canada (e.g. tax advantages, reduced infrastructure costs, etc.) ▪ **Regulations and standards** related to the environmental impact of rare earth mining ▪ **Foster collaboration** among mining companies, auto suppliers and OEMs	▪ Competing successfully with China will require measures to increase Canada's cost competitiveness (e.g., increase scale of operations by attracting foreign direct investment) (e.g., semiconductors in Taiwan, wind in Denmark)
▪ CNG/LNG: adoption	▪ Fleet owners reluctant to invest in additional vehicle premium due to risk aversion and previous poor experience with NG price volatility ▪ Lack of CNG/LNG codes and standards	▪ **Regulations and standards** – to drive adoption and to harmonize standards with those of the US ▪ **Educate and inform** fleet owners on the benefits of CNG/LNG adoption	▪ Given US will be the largest CNG/LNG fleet market, Canada could have the same standards and infrastructure to enable export ▪ Infrastructure investments would also be important in longer term

SOURCE: Expert, industry, and government interviews; market reports; McKinsey EPNG and SRP Practices

❸ Canadian governments could cultivate Canadian leadership in energy efficiency technologies

Technology area	Description of barrier	Highest potential levers	Rationale including international examples
▪ EE buildings/ industrials: adoption	▪ Although technology is economically attractive, other barriers exist such as – Limited awareness of energy efficiency gains – Risk aversion – Builders/Industrial players focus on short term returns or face lack of capital – Misaligned incentives (e.g., builders versus owners, owners versus renters)	▪ **Regulations and standards -** strengthen federal regulations and encourage and assist provincial efforts (e.g., building codes, utility regulation and revenue decoupling, energy audits, and efficiency upgrades) ▪ **Educate and inform** on the benefits of adoption given risk aversion ▪ **Direct procurement** for public sector buildings (e.g., schools, hospitals) ▪ **Incentives targeted on industrials** (e.g. interest free loan, share energy savings to pay back capex) to encourage early adoption	▪ Lack of adoption is driven by lack of awareness and understanding of the benefits despite the total cost of ownership being economically attractive. Staged regulations is the most powerful (particularly for buildings), but education and incentives are also useful levers for early adopters (e.g., building efficiency in California, industrial efficiency in the Netherlands)
▪ EE buildings/ industrials: new technology development	▪ Buildings is a commodity market with low margins and lack of talent in select areas limits RD&D spending by current industry players, slowing development of disruptive technologies ▪ Small innovative companies have difficulty attracting funding for early development and pilots	▪ **Direct investment** in government conducted research ▪ **Educate** talent through programs and funding for the development of research and vocational programs related to the sector ▪ **Regulations and standards** will spur innovation in the private sector	▪ Due to a shortage of RD&D talent in small companies, Canadian government needs to directly invest in short term. In parallel, investing in industrial education now and putting in regulations later will spur private investment. (e.g. education for oil and gas in Norway, semiconductors in Taiwan)
▪ Water: adoption of EE technologies	▪ Water utilities are risk-averse and slow to adopt new technologies: – Prefer to defer large capital investments – Favor local contracts given prior experience	▪ **Regulations and standards** to be strengthened to spur domestic innovation in low cost technologies and attract foreign investment in pilots ▪ **Foster collaboration** between utilities and industry players to encourage adoption	▪ Given the strong presence of water treatment companies in Canada, key would be to use regulations to drive innovation and sustain the advantage (e.g., water in Singapore)

SOURCE: Expert, industry, and government interviews; market reports; McKinsey EPNG and SRP Practices

4 Canadian governments could support select distributed power generation technologies – based on risk/reward calculations

Technology area	Description of barrier	Possible levers to be used	Preliminary view of risks/rewards
▪ Un-conventional hydro	▪ Long term commercial pilots to prove out the reliability of technology	▪ **Direct investment** in commercial scale pilots for low-head river projects ▪ **Incentivize adoption** through price guarantee for excess electricity	▪ Large unconventional hydro potential globally ▪ Canada has strong domestic resources and emerging potential technology leaders ▪ Strong competition and risk of copying leading to foreign purchase of Canadian IP before economic benefit to Canada
▪ Bio-energy	▪ Pilots to advance combined heat and power (CHP) technology along learning curve particularly for small-scale plants	▪ **Direct investment** in production of commercial scale pilots for combined heat & power plants to advance along learning curve and lower costs and enable whole system export	▪ Large growth in bioenergy expected in EU due to 2020 renewable targets ▪ Canada has some leadership in CHP from pulp & paper industry and innovation ▪ Regulation uncertainty for biomass as a renewable power may curb long term growth ▪ Difficult to export plants of significant size to EU
▪ Waste-to-Energy	▪ Sourcing feedstock for WTE plants is difficult given risk aversion of utilities to enter into new contracts ▪ Lack of tipping fees in Canada	▪ **Incentivize** municipal utilities to ensure feedstock availability for WTE start-ups	▪ Large untapped global potential for waste to energy, driven by high urban density ▪ Canada has potential technology leaders ▪ Foreign purchase of Canadian WTE IP before economic benefit to Canada ▪ Weak domestic market given lack of tipping fees, so pilots will need to be in US or EU
▪ Solar	▪ Pilots to prove out solar PV offgrid technology and reduce costs	▪ **Direct investment** in development of domestic solar PV off-grid pilots ▪ **Incentivize** communities to participate to pilots	▪ Large market potential particularly in developing nations with solar resources ▪ Canada has some tech and a major company ▪ Solar resources are limited in Canadian offgrid ▪ Chinese companies may focus on offgrid-PV given that it is a significant niche

SOURCE: Expert, industry, and government interviews; market reports; McKinsey EPNG and SRP Practices

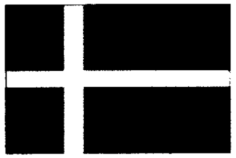
5 Canadian governments could wait for key developments before investing in technologies with potential longer-term impact

Technology area	Description of barrier	Possible levers to be used	Necessary development
▪ CCS	▪ Technology not economic without high CO_2 prices ($40-50 range)	▪ **Direct investment** in RD&D and pilots related to capture and sequestration technologies ▪ **Regulations and standards** related to carbon accounting and sequestration liability	▪ US or China make a significant commitment to mandatory carbon price at $40-50 ▪ Industry makes significant contribution and/or volunteer to reduce emissions driven by social license to operate
▪ Fuel cell systems	▪ Technology not yet economic without higher fuel efficiency standards ▪ "Chicken and egg" challenge around infrastructure investment	▪ **Incentivize** foreign investment in Canadian fuel cell vehicle production ▪ **Direct investment** in fuel-cell technology RD&D ▪ **Infrastructure investment** to incentivize mass adoption of fuel cells	▪ Break-through in catalyst research ▪ A major player invests in infrastructure ▪ Large OEM makes major bet on hydrogen, e.g., mass production for fleets
▪ Bio refineries and biofuels	▪ Cost of woody biomass low-carbon (LC) biofuel technologies is high compared with other 2nd generation biofuels ▪ Biorefinery products not yet well defined (thermal or biochemical technologies)	▪ **Direct investment** in RD&D and pilot plants ▪ **Incentivize** foreign investment through the reduction of feedstock risk with long-term contracts ▪ **Foster collaboration** to allow integration of biorefinery and CHP (e.g. gasification)	▪ A major government (or private corporation of global scale) mandate for use of bio-plastics or other bio-products (e.g. set-aside for LC fuel requirements) ▪ Breakthrough in cost position of lignocellulosic technologies ▪ Consistent and cost-effective bioproducts from thermal gasification technologies (allowing value-added synergy with CHP)

SOURCE: Expert, industry, and government interviews; market reports; McKinsey EPNG and SRP Practices

Appendix – case studies, individual technologies

Case study – Wind power in Denmark



In the 1980s, Denmark's government recognized the need for greater energy independence and lower GHG emissions

- Made a decision to accept short-term economic pain for longer-term benefit

Government used multiple levers to establish and grow its wind industry

- Investment in R&D including testing centers for new technologies
- Gradually decreasing subsidies, a carbon tax, and a Feed-in Tariff (FIT) with guaranteed grid connection reduced risk to investors by ensuring reliable revenues
- Technology standards to ensure quality
- Stable demand has reduced regulatory risk and matured the wind industry, encouraging Danish pension funds to invest

Today, Denmark is energy independent and holds 40% market share in the wind industry

SOURCE: Government websites, press search

Case study – Industrial energy efficiency in the Netherlands

[redacted]

[redacted]

Ministry of Economic Affairs makes Long Term Agreements (LTAs) with industry, which are voluntary, collaborative compacts to reduce energy intensity of operations and feedstock

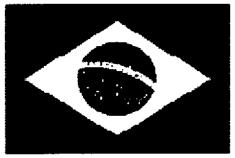
- Companies perform EE assessments, draw plans for reduction and expected impact, and monitor and report progress
- New plans are submitted every 4 years to push continual improvement and provide consistency to companies and the efficiency industry
- Efficiency measures are required to be economical with payback periods of 5 years or less
- Government agency, Senternovem, assists companies in creating plans, navigating policy, and sharing best practices

Since its inception in 1990s, LTA program has:

- Signed on over 1,000 companies representing 90% of industrial energy consumption
- Yielded a ~20% increase in efficiency

SOURCE: Government websites, press search

Case study – Ethanol in Brazil



National agency, Institute of Sugar and Alcohol, created to manage ethanol industry

- Direct investment in infrastructure projects
- Low-cost credit and financing to sugarcane industry to grow feedstock supply
- Mandatory ethanol blending in vehicle fuels; voluntary and then mandatory manufacturing targets of ethanol-only vehicles; provided industry time to adapt
- Ethanol-only government fleets provide consistent demand
- Education to create consumer demand
- Collaboration with US government to share technology and create international standards
- In response to rising prices in 2011, government implemented a temporary reduction in the fuel-blending minimum from 25% to 18%

Brazil has captured a strong share of ethanol market

- Second largest producer behind US
- For several years, was largest exporter

SOURCE: Government websites, press search

Case study – Water efficiency in Singapore

Despite limited natural resources, Singapore has become increasingly efficient due to the government's holistic approach to management:

- National supply is provided by the "Four Taps" – local water catchments, imports, reclaimed water, and desalination
- Three agencies dominate water management – the Ministry of the Environment and Water Resources (MEWR), the Public Utilities Board (PUB), and the National Environment Agency (NEA)
- Regulations: Careful land management by PUB protects reservoirs from pollution
- Government has funded R&D, facilities, and marketing campaigns for reclaimed water, called NEWater, which is fed into industrial uses and drinking supplies; also funded R&D and facilities for desalination
- Incentives: Pricing was adjusted to remove subsidies and reflect the full cost of supplying water, encouraging conservation
- Foster collaboration: The Environment and Water Industry Development Council was established to support the development of Singapore as a water research hub, including attracting foreign and private sector investment

Singapore is on-track to becoming water-independent

- Water agreements with Malaysia have been allowed to expire due to Singapore's lower needs
- Reclaimed water provides 30% of demand and desalination supplies 10%; these numbers are expected to grow to 50% and 30%, respectively, within the next few decades

SOURCE: Government websites, press search

Case study – Energy efficient buildings in California

California's Title 24 code is on the leading edge of building efficiency standards[1]

- Standards & regulations: 2014 code update will make California standards among the most efficient in the US and world
- The code is expected to continue increasing in stringency over time, offering both consistency and time to adapt
  - Independent panel of engineers decide net present value (NPV) and payback of new efficiency technologies
  - Technologies with payback of 7 years or less are included in code; builders given 3 years to adopt newly-included technologies
- Performance-based standards allow flexibility in implementation
  - Builders can either adopt designated technologies or show, using government-approved models, equivalent performance of alternative technologies, which motivates innovation
- Pairs with appliance efficiency standards and more stringent voluntary standards
- "Public goods fee" on utility bills used to fund efficiency programs and updates to the building code; reliable funding ensures continuation of efficiency efforts and consistency for the industry

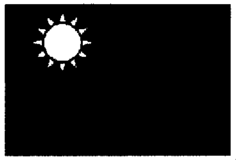
Due to building codes, other energy efficiency measures, and some climate effects, California:

- Has second-lowest per capita energy consumption of the US states
- Has experienced lower growth in total energy consumption than most other US states

1 Comparisons of codes are complicated by climate differences, but California's standards are used as a model by other jurisdictions, including US states and other countries

SOURCE: Government websites, press search

Case study – Semiconductors in Taiwan



Government intervention followed three important principles:

- Synchrony with a long-term vision
- Careful timing of intervention, including the exit of government when appropriate
- Coordination of policy across the value chain

Government identified electronics as a promising emergent technology and established agencies to facilitate its growth

- Established Electronics Research and Service Organization (ERSO) to lead development of industry, including allocating R&D funding
- Founded research centers at multiple universities
- Founded the Industrial Technology Research Institute (ITRI) to foster collaboration between industry and academia and to facilitate technology transfer from developed nations to domestic industry
- Devoted an agency to attracting foreign and expatriate talent, including streamlining immigration and raising the salary cap on foreign employees of government-funded organizations

Supported the maturation of domestic industry with tax incentives, access to knowledge and R&D funding, low-cost loans, and employee benefits such as housing and medical care

Partnered with private sector to establish foundries that have since privatized and dominated the world market

SOURCE: Government websites, press search

Case study – Exporting in Israel

Israel exports high-value-add goods (24% chemicals, 20% electronics[1]) to a diverse set of markets (24% US, 30% EU, 22% Asia, 24% other[2])

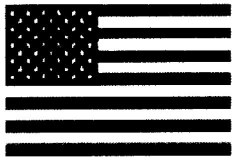
A number of government agencies offer support to domestic companies selling abroad

- Foreign Ministry sets up representative offices in target markets to introduce Israeli companies to potential trading partners and offer resources and infrastructure(e.g., office space, assistance navigating immigration law)
- America-Israel Chambers of Commerce introduce US companies and investors to Israeli industries in order to attract trade and investment
- Israel Export and International Cooperation Institute (IEICI) founded by government and private sector to facilitate exports

Israel's annual exports are worth C$80 billion

1 Includes office equipment and appliances
2 Excludes diamonds
SOURCE: Statistics Canada, Israel Central Bureau of Statistics, expert interview

Case study – Shale gas in the US



Government has provided support at each stage of the shale gas industry's development

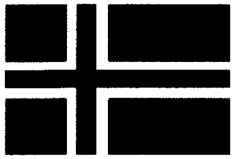
- Mineral-rights law gives landowners rather than government consistent rights to resources, encouraging exploration and exploitation of resources
- Government-funded research produced necessary equipment and processes
- Public-private partnerships demonstrated commercial-scale operations
- Production tax credit lasting ~20 years incented production before it was independently economical
- Regulations are transparent and largely standardized with some variation among States
- There is room for further research and environmental regulations to improve public acceptance

US has become a global leader in shale gas

- US companies and operations are on leading edge of technology development
- Rapid increase in production dropped natural gas prices, encouraging NG consumption, and spurred interest in exploiting shale gas resources outside the US

SOURCE: Government websites, press search

Case study – Oil and gas in Norway



Government identified four tasks for itself:
- Establish long term vision, aligned with key stakeholders, and manifested in proactive adjustments to regulations
- Leverage experience of international oil companies through a thoughtful resource access policy for frontier exploration
- Ensure competition among companies
- Support local R&D

Government used four primary instruments:
- Access to Norwegian Continental Shelf to bring in foreign players with knowledge
- Support domestic players (including government-owned Statoil)
  - Education system was adjusted to train locals and build training capacity
  - Licensing system required involvement of national players in all oil and gas (O&G) operations
  - Policies (e.g., recommendations in licenses, joint ventures facilitating knowledge transfer) encouraged contracting of domestic oil field service and equipment (OFSE) players
  - Gradually decreasing support gave national players time to develop and establish strong domestic presences before extending operations internationally
- Frequent adjustments to fiscal regime incents research, exploration, development (e.g., investments in R&D are deducted from taxable income)
- Support for innovation using a combination of levers (e.g., Statoil program provided technical and financial expertise, piloting, and mentorship for startups with O&G technologies)

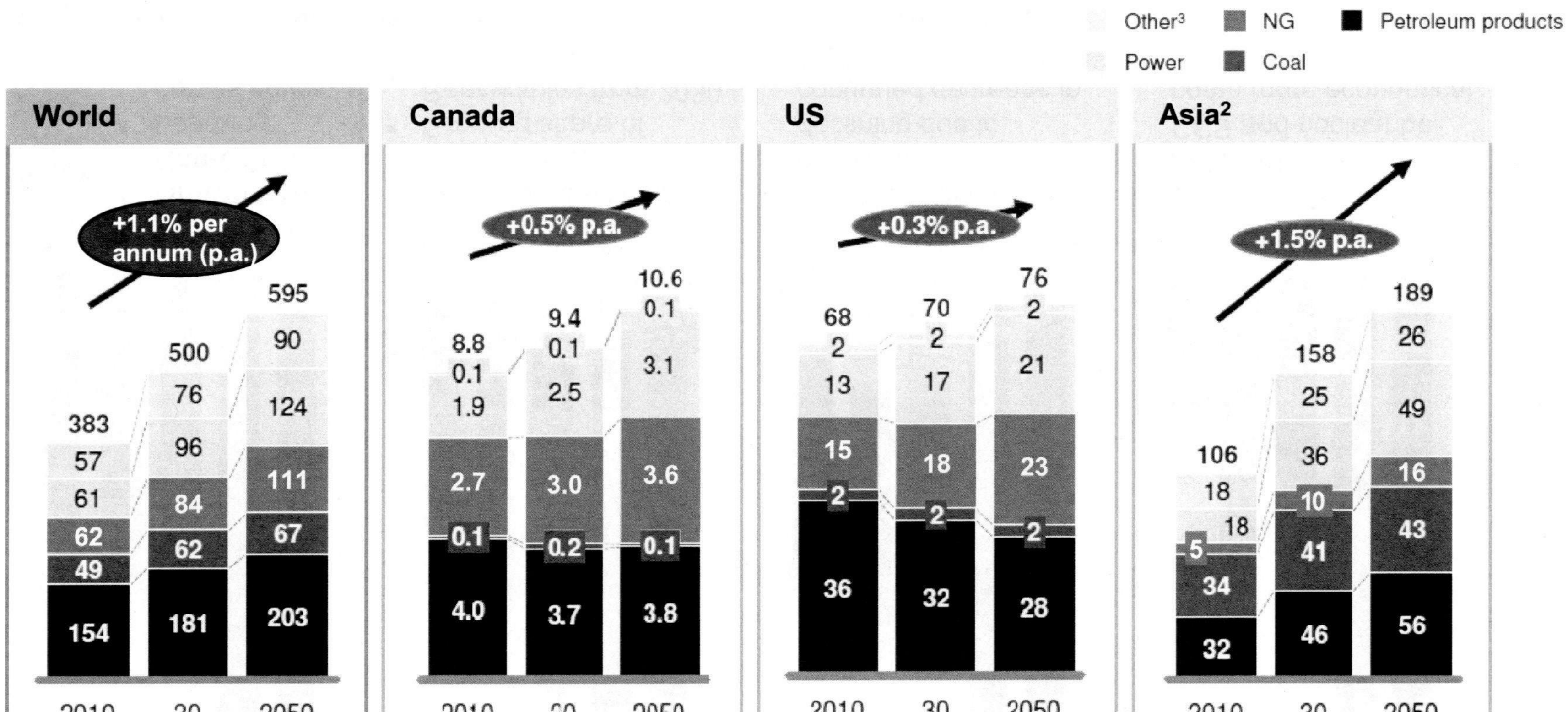
Today, Norway is third largest exporter of oil and sixth largest producer of gas
- Revenues from O&G industry fed into large Petroleum Fund and pension funds
- Norwegian OFSE sector is a key exporter with nearly half of revenue ($45 billion in 2009) from international sales

SOURCE: McKinsey EPNG Practice, press search

MCKINSEY GLOBAL ENERGY PERSPECTIVE REFERENCE CASE

Global energy demand for fossil and other fuel types

Final Energy Demand[1], QBTU



- Globally stable growth across all fuels expected, with increase in renewable energy systems (RES)
- Increase in use of gas, flat oil demand
- Decrease in oil demand, increase in gas demand
- High increase across all fuels expected

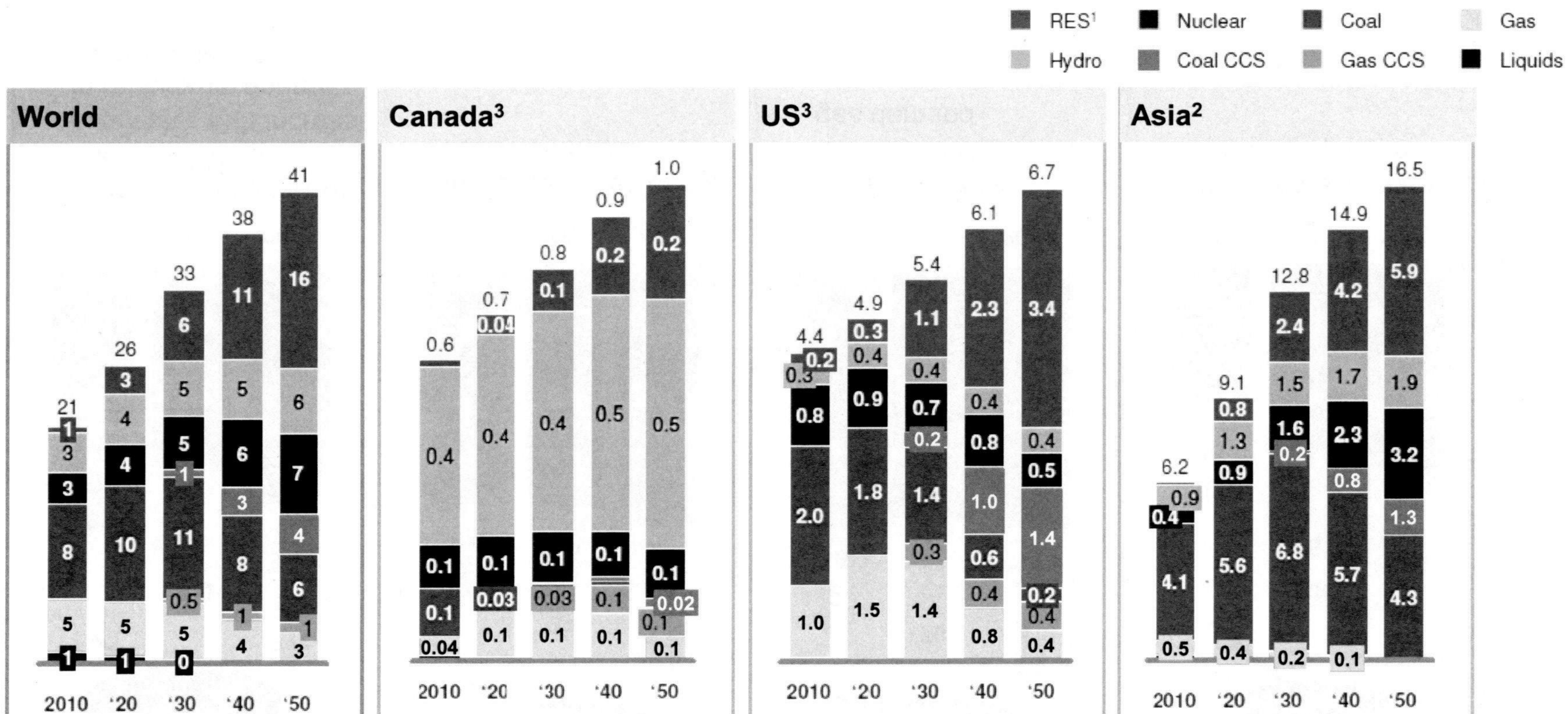
1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan
3 Other includes use of biomass, renewables etc

SOURCE: McKinsey Global Energy Perspective

MCKINSEY GLOBAL ENERGY PERSPECTIVE REFERENCE CASE

Fuel mix for power generation

Fuel mix of power production[4],('000 TWh)



Main Drivers

World:
- Growth from Non-OECD
- Learning curves drives RES

Canada:
- Hydro to retain majority of power mix
- Growing share of Renewables from 2030

US:
- Initial increase in natural gas use but declining due to continued decrease in RES cost

Asia:
- Coal growth strong until 2030, after which RES, CCS and nuclear become more economical

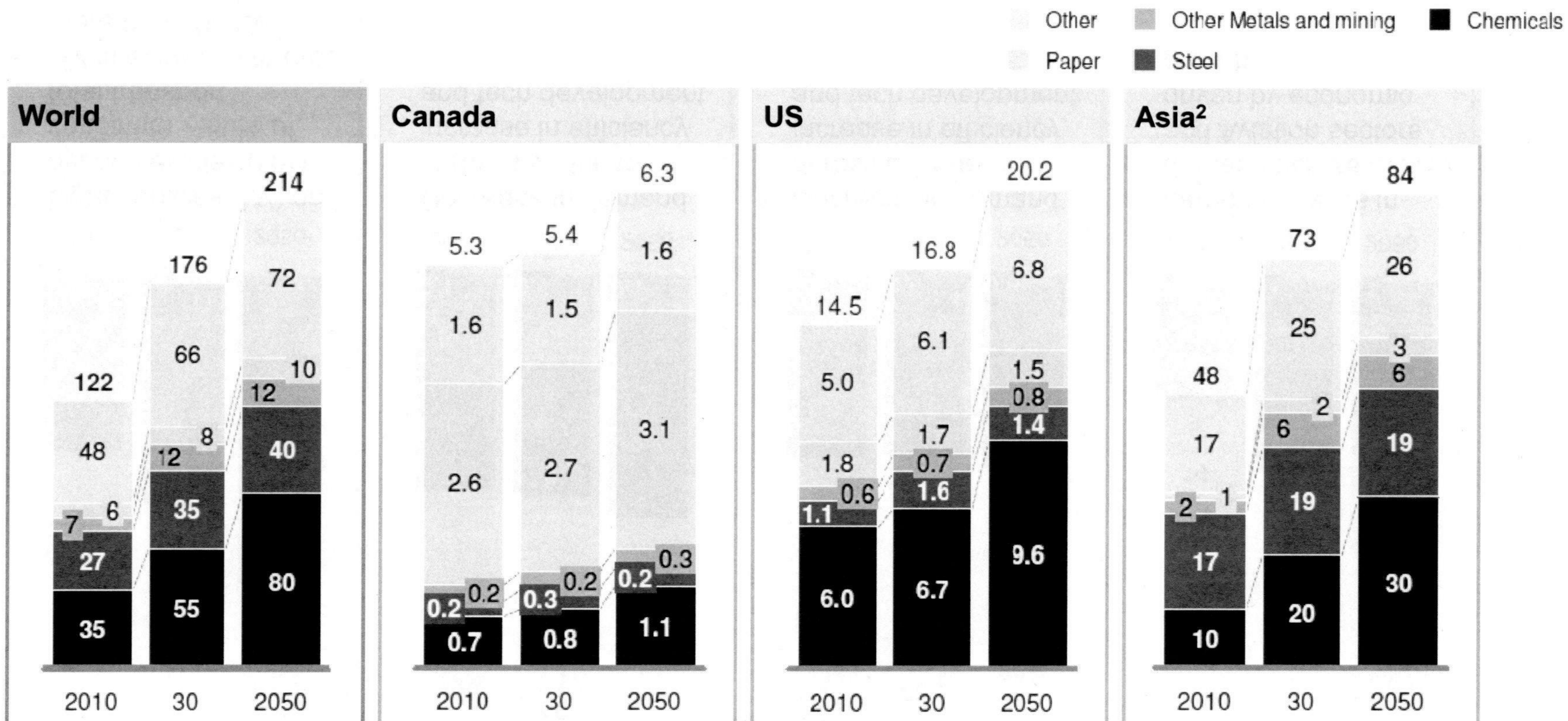
1 Renewable Energy Systems (RES) are Solar PV, Solar CSP, Wind Onshore, Wind Offshore, and Biomass
2 Asia includes India, China and Japan
3 Carbon-Capture-and-Storage (CCS) enabled by CO2-prices in US, China and Canada; no CO2-prices assumed in other non-Organization for Economic Co-operation and Development (OECD) countries
4 All of RES, Nuclear, Hydro are used for electricity production; Coal, gas and liquids used in power production are included for comparison purposes

SOURCE: McKinsey Global Energy Perspective

MCKINSEY GLOBAL ENERGY PERSPECTIVE REFERENCE CASE

Energy demand across industrial sectors

Final energy demand by sector[1], QBTU



- Chemicals and Steel are the key growth industries
- Largest growth in chemicals industry, modest or flat growth in other areas
- Largest growth in chemicals industry
- Chemicals is expected to triple by 2050 in Asia

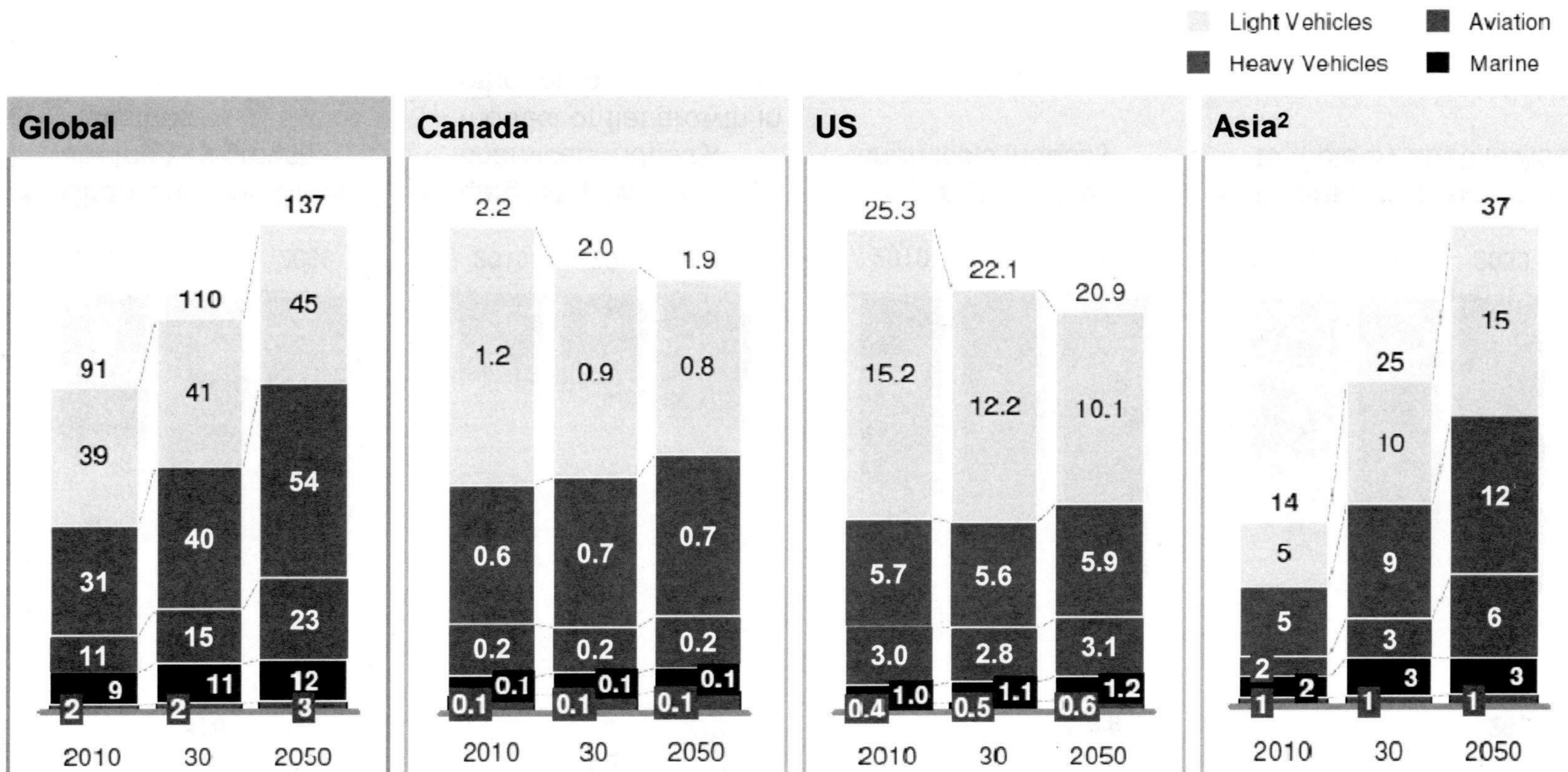
1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan

SOURCE: McKinsey Global Energy Perspective

MCKINSEY GLOBAL ENERGY PERSPECTIVE REFERENCE CASE

Energy demand across transportation sectors

Final energy demand by sector[1], QBTU



Global
- Light vehicles (LV) and hybrid vehicles (HV) constitute ~ 80% of total transport
- HV is expected to grow more than the LV sector due to EV

Canada
- Decrease in demand across LV, due to increase in efficiency and tech development

US
- Decrease in demand across LV, due to increase in efficiency and tech development

Asia[2]
- Large increases in demand across LV, HV and Aviation sectors driven by economic growth

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan

SOURCE: McKinsey Global Energy Perspective

GLOBALLY ATTRACTIVE

Fossil Fuels: Unconventional Oil

Technology Areas Under Consideration

- Drilling, extraction (including mining, steam-assisted gravity drainage (SAGD), etc) from oil sands
- Converting (including upgrading and refining) bitumen and heavy oil for export
- Environmental (water, land, air) technologies and remediation; tailings management
- Domestic pipelines and pipeline technologies

Canada has a clear advantage

Market and Tech Overview

The oil sands market is large and fast growing driven by worldwide demand for oil and advances in extraction technology :

Large and fast-growing global market for oil sands crude, economic at oil prices > $60-70/barrel (bbl)

- Third largest oil reserve (175 billion barrel of oil equivalent (BBOE))
- $100-200B market by 2020 in oil derived from oil sands, with most growth from in-situ sources (80%)
- Several paths to market with varying economics
  - Export via US refineries (discount due to oversupply and transport cost)
  - Export to international markets (limited today by pipeline capacity)
  - Domestic use (limited demand)
  - Upgrading and export of more refined products (high capital cost, but saves on transportation)

Full scale pilots are needed to prove new technology development

- All players improving SAGD[1] front end – electrothermal and radio frequency (RF) heating, solvents, in-situ steam
- Continuing improvement of environmental (water, air, land) technologies

Pipelines are essential for oil & gas distribution

- Pipeline construction worldwide was $60B in 2012
- Majority of pipeline build in Asia
- Most innovation is on safety and cost reduction

Canada's Advantage

Canada has large oil sands resources and several domestic companies well positioned to capture and exploit its value:

Canadian companies are present along the entire value chain

- Continuing merger and acquisition (M&A) activity

Leading technologies are developed in Canada

- SAGD result of successful provincial and Federal Canadian gov't/industry collaboration
- Canada's Oil Sands Innovation Alliance (COSIA) – Canadian consortium, improving tailings management, GHG and land remediation

Canadian access to global markets may be limited

- Export of resource limited by pipeline capacity
- Canadian refineries currently configured for lighter oils
- Canadian oil sands technologies may not be applicable in other heavy oil deposits (e.g., Venezuela)

Canadian expertise in pipelines and monitoring technologies

- Major global companies
- Some new technology for Intrusive robots to monitor pipe wall thickness
- External monitors to listen for changes in pipeline condition

Investment thesis

To maintain Canada's advantage, Canada could continue to rapidly innovate drilling, extraction and other technologies, lower barriers to oil export (e.g., more cost effective and safe pipelines) and seek additional applications for oil-sands technologies

- **Lower the cost of Canadian oil exports by continuing through pilot and full-scale testing of in-situ extraction technologies**
  - Multinationals already making large R&D efforts
- **Develop advanced environmental technologies for domestic and export use in other markets**
  - Oil-sands require advanced environmental technologies that are transferrable to mining and other industries

1 Steam Assisted Gravity Drainage – for in-situ extraction, steam pumped into well heats bitumen, increases flow

SOURCE: McKinsey Oil and Gas Practice, Market research, expert interviews

GLOBALLY ATTRACTIVE

Fossil Fuels: Unconventional Gas

Technology Areas Under Consideration

- Shale gas extraction (drilling, fracturing, completion, environmental management)
- Supply chain management, field management, field exploration and evaluation
- Gas-to-liquids (GTL) technologies

Canada has a clear advantage

Market and Tech Overview

Large fast growing market globally with incremental technology improvements

Fast growth driven by drilling and fracturing technologies

- Shale gas 30% of NA, 50% of US gas production by 2020
  - 16-30% will come from outside NA: China and Australia
- By 2020, oilfield services spend in NA $38B (shale) $7B (tight) <$1B (coalbed methane (CBM)), $18B (drilling)

Incremental improvements in technology

- Drilling innovation incremental, practical, easily copied, specialized to geology
- Opportunities in supply chain management, field management, field exploration, network

Environmental opposition presents challenges and opportunities

- Fracking bans in Quebec, France
- Some concerns regarding seismic activity
- Water pollution concerns present opportunity to lead in water treatment

GTL technology energy-intensive and immature, some incremental improvements to serve smaller fields

Canada's Advantage

Canada has extensive shale gas resources and some horizontal well drilling expertise

Canada has significant shale gas resources

- Extensive resources in Ontario, Quebec, British Columbia, Alberta, Nova Scotia and New Brunswick
  - Ordovician Utica Shale and Devonian Muskwa Shale hold 10 trillion cubic feet (Tcf) of recoverable gas

Canada has horizontal well drilling expertise, but not holders of technology

- US OFSEs have 40% market share in pumping and fracturing, and 80% completion

Canada has many smaller drilling companies with expertise in Canadian shale gas basins

- Drilling, pumps, pipes and fracking about 50-60% of cost
- Multinationals willing to develop smaller operators (<50 rigs) into larger regionals with track records
- Some potential for operation outside Canada (e.g. NA or China), but dependent on geology

Canada has little GTL technology, but is attracting GTL potential due to its vast resources

Investment thesis

To maintain Canada's advantage, Canada could seek opportunities to export shale gas, stimulate the domestic market for NG and potentially export services

Domestic, regional gas services (drilling, water) in Canadian basins

- Regional Canadian players have first mover advantages, particularly if water and other regulations are systematically tightened
- Possible export in services (likely not technology) to international areas where shale is similar to Horn River, Montney, or where water regulations are also being tightened

Grow Canadian players in other technology areas

- Canadian NG have opportunity to grow market share by taking advantage of access to local regional drillers/suppliers

SOURCE: McKinsey Oil and Gas Practice, Market research, expert interviews

Fossil Fuels: Enhanced Hydrocarbon Recovery

Technology Areas Under Consideration

- Enhanced oil recovery (EOR) using thermal, CO_2 or hydrocarbon injection (includes capex and operations)
- Coal bed methane (CBM) recovery using CO_2 injection (includes capex and operations)
- Gas hydrate extraction

Other countries have a clear advantage

Market and Tech Overview

Enhanced hydrocarbon recovery is a large and growing market driven by depletion of large oil fields and increasing oil and gas prices, with mature technologies for EOR and room for technological development in CBM

Large and moderately growing market, driven by EOR in US and CBM in China

- $126B market in 2011 for EOR, moderate growth driven by US where there are large natural CO_2 deposits
- $9B market in 2011 for CBM, high growth driven by China's lack of natural gas resources

Technology relatively mature for EOR, but immature for CBM and gas hydrates

- EOR technologies are well established, though now people are experimenting with NG injection
- CBM technologies are still immature
- Gas hydrate extraction still in R&D stages, not economical

Economic attractiveness depends on oil and gas prices

- Both EOR and CBM are only economic at higher prices, may not be economically sensible to develop EOR with current gas oversupply

Canada's Advantage

Canada has large natural oil and coal resources, but US, China and Russia are technology and market leaders today

Canada has large oil and coal resources

- 3rd largest unconventional oil resources
- Large coal deposits, but only the 10th largest producer of coal given domestic hydro resources
- CBM currently uneconomical due to shale gas
- Methane hydrate not economical until shale, CBM resources depleted

Canada has some subsurface expertise, but US/China has application specific expertise

- Weyburn-Midale CO_2 EOR and sequestration project running since 2000
- Several Canadian players driving innovation (e.g. polymer and water floods)
- EOR-specific expertise is in US today, held by large oil and gas players
- CBM-specific expertise is in China and Russia today, held by domestic companies and academic institutes
- Canadian companies are developing technologies for economic extraction of gas hydrates

Investment thesis

Canada can best derive value by adopting EOR for its conventional oil reserves, and in the long term, collaborating with China to develop CBM extraction techniques

Adopt EOR for conventional and export the oil to US/China

- EOR adds another $20-25/barrel cost to regular operations, and is therefore economic only at oil prices above $60-70/barrel, which are expected to continue

Collaborate with China to develop more effective CBM and low cost EOR techniques

- Today, there are issues with CO_2 injection into CBM as it causes fissures
- Collaboration with either Chinese academic institutions or companies

SOURCE: McKinsey Oil and Gas Practice, Market research, expert interviews

STRATEGICALLY IMPORTANT FOR CANADA

Fossil Fuels: Carbon Capture & Storage

Technology Areas Under Consideration

- Pre-combustion, oxy-fuel, post-combustion carbon capture
- Carbon storage and transport
- Coal, Natural gas CCS new builds, CCS retrofit

Potential long term opportunity

Market and Tech Overview

The CCS market is small, with growth dependent on carbon price (likely 2030+), and does not yet have a clear technological pathway:

CCS slow growth until 2030+ and requires carbon market with high CO_2 prices

- Driven by EOR growth
- $4.2B in capital expenditures in 2020, mostly NG CCS
- $260B in capital expenditures in 2030, even mix of gas CCS, coal CCS, and retrofits, though timing highly dependent on carbon price regulatory adoption

Technologies are still immature without a clear winner

- Oxyfuel, pre & post-combustion all promising in bench pilots, but need testing at scale
- Storage and transportation technologies also need to come down on cost, while new methods are being explored (e.g., cement sequestration)

Uncertain public opinion regarding additional energy consumption and CO_2 leakage

- Public uncertainty of CO_2 spontaneous release
- Coal phase-out in Ontario
- Undecided on carbon pricing

Canada's Advantage

Canada has made large investments in CCS technology development and pilots

Large investments by Canadian gov't

- Federal $1.4B in 2008
- Alberta $2B in 2008

Several large-scale industrial-scale projects underway

Some startup technology development activity

Investment thesis

Canada can capture value by continuing long-term R&D and while combining with existing industrial processes for near term returns

Long term R&D for new builds or retrofit

- Allows development of new science and private R&D growth in Canada
  - New tech or significant improvements likely in 10+ years, i.e. 2nd generation CCS

Develop processes that co-generate and/or use CO_2

- Sequester CO_2 locally as part of product manufacturing process
- CO_2 used to form carbonate in mining to separate base minerals from ore
- Direct liquid CO_2 generation
- Most savings come from co-location of CO_2 generation and usage

1 Intensified Temperature Swing Adsorption; structured adsorbent on fixed frame that rotates

SOURCE: McKinsey Oil and Gas Practice, Market research, expert interviews

STRATEGICALLY IMPORTANT FOR CANADA

Fossil Fuels: Gasification

Technology Areas Under Consideration

- Gasification equipment that turns coal into chemicals or fuel gases
- Not considered are technologies that turn biomass or municipal solid waste (MSW) into fuels

Other countries have a clear advantage

Market and Tech Overview

The gasification market is small and moderately growing, with some regional applications (i.e. China)

Small and moderately growing market, mostly driven by China
- $4B equipment market globally, projected to grow quickly through 2015 then slow down
- Many coal gasification projects are in Chinese chemicals manufacturing and power industry

Technology relatively mature but not economic without subsidies
- Coal gasification technology is relatively mature
- Requires government funding to be economic

Economic attractiveness depends on local fuel mix dynamics and regional government
- Coal gasification attractive in China today because they are long on coal and short on gas, plus large chemicals industry
- Coal gasification not economically attractive in most regions
- Coal gasification projects regulated by Chinese government

Canada's Advantage

Although Canada has large coal deposits, there is limited economic value in using gasification technologies domestically, and global leaders in gasification technologies are focusing on other markets

Canada has large coal deposits, but limited domestic need for gasification
- Large coal deposits, but only the 10th largest producer of coal as Canadian hydro and nuclear are inexpensive
- 3rd largest forests globally
- Given the abundance of natural gas in Canada, there is limited need for domestic gasification

Canada has limited market and technology presence in gasification
- Chinese players are entering the market with me-too products

Investment thesis

Canada's technology opportunity is limited to adopting gasification technologies to biomass

Gasification does produce syngas, which could be used as precursor to higher-value industrial materials and fuels
- R&D efforts into improving CO/H_2 mix in syngas
- Will likely be more expensive than traditionally derived products, but could be economical with use of residue biomass material (see Biofuels/Biorefinery)

Unlikely to be able to export equipment and services to China
- Global leaders already in Chinese market
- China is already developing domestic technology players

SOURCE: McKinsey Oil and Gas Practice, Market research, expert interviews

Renewables and Clean Energy: Solar PV

Technology Areas Under Consideration

- Early value chain (polySi, ingot/wafer, cell/module) commoditized – heavy cost pressure, large global players
- Balance of System (BOS) value chain (inverter, mounting, cables, installation) has large cost pressure
- Increasing specialization later in value chain (project development, engineering, procurement and construction (EPC), power production ownership)
- Concentrated solar PV

Canada could take lead in emerging market

Market and Tech Overview

Large and fast growing market but highly commoditized through most of the value chain (with China dominating manufacturing):

PV panel market expected to reach $325B by 2020, $962B by 2030

- Market driven by increasing power demand and decreasing production cost (40% by 2015, 60% by 2030)
- Large expenditures in Asia ($440B in 2030) to meet power needs

Value chain is commoditized, some opportunities in niche downstream applications

- Most innovation through incremental improvements in efficiency and scale
- Large investments in China have resulted in oversupply that will drive consolidation upstream
- Downstream will become specialized to serve final customer needs

Concentrated PV market small, pilot stage tech

- Many companies insolvent or undergoing acquisitions
- Long term competition with low cost thin film PV
- Most competitive in larger, direct sun installations
- Lower cost-of-entry due to less PV content
- Concentrator photovoltaic (CPV) industry installed 40MW in 2011

Canada's Advantage

Canada has a large scale solar company which is an established low-cost player and several smaller companies, with limited domestic need for solar power

Canada has several smaller companies with significant VC backing, but finding difficulty in breaking into market

- >150M VC capital paid-to-date
- Mix of companies along value chain
- Many companies being acquired or facing significant operating problems[1]

Canada has little domestic need for solar except in niche areas

- Solar more expensive even during peak hours given hydro/nuclear as base load, gas for peak
- Could have advantage for offgrid and rural power generation

Investment thesis

Canada's opportunity is to focus on niches such as offgrid power generation for domestic and possible export use

Offgrid power generation

- Offgrid areas (e.g. rural areas with high distribution costs) may benefit from local power generation
- If Canada develops integrated solutions (e.g., solar+ diesel+ water), could be exportable to developing nations

Grow downstream solar systems integrators and applications

- Smaller players can serve regional utilities and companies in domestic Smart Grid applications
- With sufficient expertise could expand to NA market

Niche play in concentrated solar PV

- Many challenges in solar PV are in systems integration and installation
- Unclear if there is a sustainable CDN advantage

1 US National Renewable Energy Laboratory (NREL) "Opportunities and Challenges for Development of a Mature Concentrating Photovoltaic Industry", August 2012

SOURCE: McKinsey Sustainability and Resource Productivity Practice

Renewables and Clean Energy: Wind

Technology Areas Under Consideration

- Wind turbine suppliers (tower, blade, generator, power electronics), OEMs and operators
- Advanced Drive Trains (e.g. permanent magnet generators, advanced gearboxes, rotors, wind forecasting)

Other countries have a clear advantage

Market and Tech Overview

The global market for wind is large, but mostly cost driven with large global players outside Canada and incremental technology innovation

Wind global market to grow to $680B by 2020
- Largest growth in US, Europe and China

Most of value chain is cost driven, with incremental technology development
- Entry of Chinese manufacturers has led to widespread cost pressure
- Increasing standardization of components leads to commoditization
- OEMs optimizing supply chains also placing pressure on suppliers

Continuing incremental technology innovation
- Increase in drivetrain reliability through new gearbox and generator technologies
- Increases in overall efficiency through wind forecasting, dynamic load modulation and rotor designs

Canada's Advantage

Although Canada has domestic wind resources, most power will still be obtained from hydropower/nuclear, and it does not have any well-established wind turbine generator (WTG) players

Canada has domestic wind resources
- Canada has large areas suited to wind farms
- Wind is a potentially cost-effective energy source for remote locations where long-distance power distribution is expensive

Most manufacturing and innovation will be led by Chinese and EU players
- Canada will not have cost or expertise advantage in most areas
- Proximity to US does not reduce cost enough to compete with offshore production
- Specialized components (e.g. cold-weather blades) could be niche but will be competing with Denmark and other EU countries with cold climates

Wind energy is politically favorable and there is a FIT program in Ontario
- FIT programs have encouraged installation of wind farms

Investment thesis

Canada's opportunity is limited to niche domestic consumption

Offgrid power generation
- Wind may be more economical for niche remote applications where long-distance distribution is expensive
- Competing with natural gas and coal, not suitable as sole baseline energy source

Supplementary RES
- Net economic value must be determined in light of inexpensive hydro and nuclear power generation

High technology component supply
- Smaller suppliers could develop advanced components and operational technologies (e.g. wind-forecasting, load modulation)
- Unclear if there is a sustainable Canadian advantage

SOURCE: McKinsey Sustainability and Resource Productivity Practice

STRATEGICALLY IMPORTANT FOR CANADA

Renewables and Clean Energy: Geothermal

Technology Areas Under Consideration

- Power generation using geothermal resources
- Combined Heat and Power (CHP) applications
- Does not include ground source heat pump applications

Other countries have a clear advantage

Market and Tech Overview

Geothermal is a small, slowly growing market with mature technology

Small and slow growth market
- Small market today $3B, mostly in US, Japan
- Most geothermal in Canada located near low-cost hydro, so few incentives for utilities to develop geothermal capacity

Technology is mature with established global leaders
- Technologies for power generation are mature across the value chain
- Technologies for Combined Heat Power are also relatively mature
- Global technology and market leaders already well-established (US, Japan)

Canada's Advantage

Although Canada has large geothermal potential, most of these are not economic given hydro resources, and most technology leaders are in the US and Japan

Canada has large geothermal potential and drilling/exploration experiences and expertise
- Large untapped potential in geo thermal resources, but not as attractive as some other countries
- Historically has not been developed given availability of hydro and nuclear power
- Hot water coming to surface from conventional operations
- Western Sedimentary Basin mapped
- Extensive human resources and business infrastructure for drilling in Western Canada

US and Japan are the market and technology leaders
- Most attractive geothermal resources are in select countries, e.g., US, Japan, New Zealand and Iceland
- As a result, the same countries have developed the technology and market domestically

Investment thesis

Canada's opportunities in geothermal are limited to domestic power generation (where regionally economic) and some CHP applications

Potential for domestic power generation and CHP
- Could be attractive for offgrid applications or integration with building in rural communities
- Canadian Geothermal Energy Association (CanGEA) estimates 5000MW of accessible geothermal in Western Canada

SOURCE: McKinsey Sustainability and Resource Productivity Practice

Renewables and Clean Energy: Uranium Mining

Technology Areas Under Consideration

- Uranium mining , conversion, fuel fabrication and reclamation
- Mining waste management

Canada has a clear advantage

Market and Tech Overview

The global market for uranium and derivative products is large and growing, driven by continued nuclear builds in Asia, with continuing technological innovation

Large global markets in mining and conversion
- $14B mining market by 2020, 5% compound annual growth rate (CAGR), 23% margins,
- $8B conversion, storage and reprocessing market by 2020, 2% CAGR, 5-10% margins

Technology for mining is advancing in niches:
- Methods for efficient and environmentally friendly extraction of uranium ore, refinement and fuel-rod production
- Nuclear base-load matching using load control and energy storage
- Reclamation of spent nuclear material
- Waste management and conversion to revenue products and disposal
- Radiation, health and safety monitoring technologies; early detection and response

Canada's Advantage

Canada has large uranium resources and is well established in supplying global markets

Uranium resources and mining majors
- 3rd highest uranium reserves
- 2nd highest for extraction
- Underground/open mines with heap leaching of low grade ore

Investment thesis

Canada's opportunity is to maintain its position as a top uranium mining nation

SOURCE: McKinsey Electricity, Power, Nuclear and Generation Practice

Renewables and Clean Energy: Nuclear Technologies

Technology Areas Under Consideration

- New reactor construction (reactor, containment, power generation, utilities)
- Reactor decommissioning (nuclear waste handling, worker safety)
- Advanced Fuel cycles
- Small scale nuclear reactors (design, manufacturing)
- Nuclear fusion

Other countries have a clear advantage

Market and Tech Overview

The nuclear reactor market has new builds, opportunities in refurbishment and decommissioning, and long-term technology development in miniature fission and fusion

Most new construction of nuclear power plants in China, France and Russia

- $400B capital expenditures in 2020, mostly in China and Russia
- Delays in Japan and EU due to Fukushima
- $5-6B/unit (1GW)
- Large gov't backed projects, strong advantage to domestic companies and local contractors
- Some activity in thorium based reactors

Refurbishment and decommissioning

- 45-50 GW to retire in US and Japan by 2030
- $1-2B/refurbishment

Small nuclear plants

- Immature technology for remote off grid, industrial applications
- Technology leaders not in Canada

Nuclear fusion

- Still in early stage R&D, with multiple large efforts across US, Asia, EU
- No major roadblocks, but large engineering hurdles making timeline uncertain (>20 years)

Canada's Advantage

Canada has expertise in niche technology development, including CANDU reactor expertise

Canada has some development of technologies to increase the efficiency and environmental friendliness of nuclear plants

Canada has a small-scale fusion reactor effort

Investment thesis

Canada has little opportunity in new reactor builds based on current Candu design

Long term development of next generation fission reactors for domestic use

Small nuclear plants/Fusion

- Long term potential, but significant investment required

SOURCE: McKinsey Electricity, Power, Nuclear and Generation Practice

GLOBALLY ATTRACTIVE

Renewables and Clean Energy: Bioenergy

Technology Areas Under Consideration

- Biopower (electricity)
- Bioheat
- Biomass collection, processing, and densification

Canada could take lead in emerging market

Market and Tech Overview

The biopower market is fast growing, with mature technology, but is regionally driven, with most of the growth in EU due to regulatory requirements

Small 2012 market for biopower, but fast growth
- $100-200B in capital expenditures in 2020, declining after 2020
- EU markets require biopower due to 20% renewable regulatory requirement by 2020
- Largest capital expenditures in EU and China

Biopower is mature technology
- Retrofit of coal plants is well proven and looking for cost reduction opportunities
- Densification technology is critical for export markets and also relatively mature, with some R&D focused on minor efficiency gains
- Economical biomass collection and processing is significant part of cost, as it is labor intensive

Uncertain public opinion and environmental risks of plant based bioenergy

Canada's Advantage

Canada has large forests and some export potential for pellets, but is not a clear technology leader

Canada has vast forest resources and industry expertise including mill waste and beetle-kill
- Technological leaders in efficient forestry operations, although high labour costs and difficulty to export
- Underemployed forestry workforce

Export market for Canadian wood pellets is small
- Canada currently exports <$500M USD in wood pellets to EU

Some technology development in bioenergy CHP systems

Investment thesis

Canada's opportunity is to develop exportable biomass technologies

Shift to small-scale CHP niche investments for technology
- Large scale bioenergy projects in China or EU unlikely to import CAD technology since combustion/gasification is mature technology

Higher value technologies can be derived by integrating biorefinery concept
- R&D in biorefinery is still fragmented, heavy investment in US and EU academic/industry partnerships
- Integration of biorefinery into current thermal gasification technologies is closest technology to commercialization

SOURCE: McKinsey Oil and Gas Practice, Market research, expert interviews

Renewables and Clean Energy: Biofuels/Biorefinery

Technology Areas Under Consideration

- Next generation biofuels
- Drop-in fuels
- Biogas
- Value added biorefinery products

Potential long term opportunity

Market and Tech Overview

Biofuels markets are large and growing driven by demand for RES, with continuing innovation in 2nd generation biofuels

Bioethanol is large and established market, with greater growth driven by demand for renewable fuels and energy security

- 2010: 98 GL bioethanol demand (51 in US), 23 GL biodiesel (mostly EU)
- 2020: 260 GL bioethanol (89 in US), 64 GL biodiesel (EU and Asia)
- 360 new advanced biofuel (e.g., cellulosic) plants needed in US by 2022 to meet Renewable Fuel Standard 2 (RFS2) mandate (16 GL cellulosic biofuel), only 30 new conventional biofuel plants needed

Woody biomass biorefineries require further R&D

- Biorefinery products likely >10 years away using enzymatic or biochemical processes
- Some biorefinery integration using current gasification techologies (e.g, CHP), but high-value products are uncertain and unreliable due to variability in syngas stream

Biogas is less attractive in markets where inexpensive natural gas is available

Canada's Advantage

Canada has large forests, but these may not be the best precursors for bulk biofuels (e.g. diesel and ethanol), with most industry leaders are in EU/US

Canada has vast ligno-cellulosic feedstock resources (forests, forest residue, and forest processing by-products)

- Lignocellulose not preferred feedstock, due to pretreatment requirements

Significant industry activity in producing 2nd generation biofuels, but mostly in US/EU

- $3B in capital expenditures over next three years for ~1BL/yr cellulosic ethanol, almost all in USA, almost all with agricultural residues

Investment thesis

Canada's opportunity is greater R&D for value-added forest products (e.g. biorefinery)

Woody biomass biorefinery is long-term source of value-added forest products

- Unlikely to compete with agricultural waste for LC ethanol production
- Niche LC chemistry R&D required
- Proven applications of integration with thermal gasification (e.g., CHP) might be closest technology to commercialization

SOURCE: McKinsey Oil and Gas Practice, Market research, expert interviews

STRATEGICALLY IMPORTANT FOR CANADA

Renewables and Clean Energy: Conventional Hydroelectric

Technology Areas Under Consideration

- Conventional hydroelectricity technology (turbines & generators)
- Hydro project management

Canada has a clear advantage

Market and Tech Overview

The hydropower market is large worldwide, but markets tend to be regional, with mature technologies owned by EU firms

Hydro is slow growth, but high value
- $420B in capital expenditures in 2020

Mature technologies, mostly EU owned tech
- 3 EU majors (Alstrom, Andritz)
- Fast growth in BRIC companies
- Increasing cost pressure from China

Limited exportability
- Much of worldwide hydro is state owned
- Emerging markets likely to use domestic rather than foreign engineering
- Net exporter of electricity to US: $3.8B @ $64.91/megawatt hour (Mwh), in exports, $1.3 B @ $56.59/Mwh in imports in 2008

Canada's Advantage

Canada has large domestic hydropower resources and some project management engineering expertise, but top ten technology manufacturers are located elsewhere

Vast water resources and hydroelectric capacity
- 3rd largest hydroelectric power producer in the world
- Attracts energy intensive manufacturing

Project management engineering expertise
- Including international contractors for siting, preparation, heavy civil engineering

No Canadian companies in top 10 turbine or generator manufacturers
- Some presence of EU companies in Canada

Investment thesis

Canada's opportunity is to continue to attract power-intensive industries and export power to the US

Canada could export project management engineering expertise
- Only place in conventional hydro value chain Canada is likely to compete

SOURCE: McKinsey Electricity, Power, Nuclear and Generation Practice

STRATEGICALLY IMPORTANT FOR CANADA

Renewables and Clean Energy: Unconventional Hydro/Marine

Technology Areas Under Consideration

- Run of river hydro and low-head hydrokinetic (in-river)
- Tidal, wave (marine) energy

Canada could take lead in emerging market

Market and Tech Overview

The unconventional hydro market is still nascent with new technologies on the horizon but no clear winner

All unconventional hydro markets are fragmented with moderate R&D, but still anyone's game

- Most feasibility studies determine too costly for amount of power produced

Marine is niche market in some coastal zones

- Most feasibility studies determine too costly for amount of power produced
- Wave energy is also a niche market, and still immature technology

Hydrokinetic (in-river) has large global potential

- 100 GW global capacity of in-river
- Many small start-ups with pilots, mostly in US
- Seems likely to see commercial pilots within 5 years

Canada's Advantage

Canada has both large hydropower resources and technical expertise in innovative hydropower technologies

Large hydropower resources and hydroelectric expertise

- 3rd largest hydroelectric power producer in the world
- Engineering expertise (turbines, fluid mechanics) transferable to unconventional hydro

Several companies developing run of river hydro technologies, likely competition with US companies

- 70 preliminary permits for hydrokinetic in US

Investment thesis

Canada's opportunity is to commercialize and export unconventional hydro technologies

Low-head hydrokinetic turbines have export potential, but may be difficult to prevent entry of large players

- Easy to export small units
- Danger in copying and low barriers to entry
- Immediate scale-up, protect key IP, while focusing on cost reduction for small units for fast adoption and to maintain market share

SOURCE: McKinsey Electricity, Power, Nuclear and Generation Practice

Distribution: Smart Grid (AMI, HAN, Demand/Management, Appliances)

Technology Areas Under Consideration

- Automated Meter Integration (AMI), Home area network (HAN)
- Demand management/response, storage, appliances, program management, financial services

Other countries have a clear advantage

Market and Tech Overview

Smart grid market is large and rapidly growing, but highly commoditized at most points in the value chain

Overall Smart Grid market $41B in 2011 and rapidly growing
- Market driven by long term shift of utilities worldwide to Smart Grid distribution systems
- Market is a mix of global and regional suppliers and (generally) highly fragmented utilities markets

Equipment and network infrastructure value chain commoditized
- Upstream components have little innovation (with exception of power electronics in transmission/distribution), and are commoditized
- Limited opportunities for entry downstream
- Slow adoption by risk-averse utilities
- Some first-mover advantage in software

Major technical issues in Smart Grid pilots include:
- **Cost estimation –** difficult to estimate system costs, overruns publicized
- **Standards** in many cases not yet in place and can cause delays
- **Pricing and distribution models** are difficult to evaluate except at scale, and so are risky
- **Integration of local power sources and large drains** (e.g. PV, storage and EV) still experimental

Canada's Advantage

Canada has some domestic players downstream in the value chain and a less fragmented utilities market than in the US, but most global players are located elsewhere

Canada has a less fragmented utilities market than US
- In majority of provinces, utilities are vertically integrated Crown corporations with some investor owned distributors
- Smart-meter rollouts in Ontario completed in 2010, giving some Canadian companies early advantage
- **Downside:** Crown corporations may be able to implement Smart Grids quickly but may not be economical or exportable
- New Brunswick (NB) Power entering multi-year smart-grid program
  - Part of NB Power reduce and shift demand (RASD) energy blueprint
  - Includes smart thermostats, appliances, dashboards, thermal storage
  - R&D center to create 40 new jobs

Canada has several Smart Grid startups, but no clear winners

Investment thesis

Canada can gain domestic benefits by adopting Smart Grid technologies early and attracting foreign players willing to invest in Canadian markets

Domestic gains from early Smart Grid adoption
- Early adoption could lead to lower domestic power prices, higher utilization of existing resources
- Power utilities are concentrated on EV charging infrastructure, speeding domestic development
- Software and integration are often regional utility-scale solutions

Attract manufacturers and local development of Smart Grid appliances and equipment
- Could bring smart grid manufacturing to Canada
- PV and vehicle integration still being developed
- Downside: margins in Smart Grid appliances slim (5%)
- Other countries following same strategy

SOURCE: McKinsey Sustainability and Resource Productivity Practice

GLOBALLY ATTRACTIVE

Distribution: Smart Grid (Power electronics in T&D)

Technology Areas Under Consideration

- Power electronics used in distribution: transformers, high-voltage direct current (HVDC), flexible AC transmission systems (FACTS), fault-detection/isolation/resolution, switching, sensing, volt-var, PV and wind power conversion
- Not included is power electronics in vehicles (specialized supply chain described in EV) and consumer electronics (not part of large scale power distribution)

Other countries have a clear advantage

Market and Tech Overview

Power electronics in smartgrid transmission and distribution (T&D) is a large and growing market, with both continuous innovation and the possibility of disruptive change on the horizon

Power electronics in distribution to grow to $10B by 2020

- 3x market growth from 2010
- Driven by large growth in wind and PV markets
- Longer term growth expected in transmission and distribution markets with introduction of thyristor replacements

Continuous Silicon (SI)-based technology improvement with disruptive silicon carbide (SiC) and gallium nitride (GaN) chips on the horizon

- Si-based semiconductor and package cost and performance continually improving
- SiC- and GaN based components still at early stage (laboratory and limited production) but recognized as potentially disruptive
- Chip production likely to be in a few large fabrication facilities
- Power module design still open to innovation and new applications

Canada's Advantage

Most innovation in power electronics is outside Canada, driven by large capital investments and strong consumer and auto industries

Most manufacturing and innovation well developed and located in US, EU and Japan, not Canada

- Large development costs including fabrication facilities, R&D pipeline and supplier networks
- Large players dominate upstream in value chain due to large fixed costs (semiconductor manufacturing and module packaging)
- Development also driven by large consumer electronics, PV, wind and EV industries
- Many players also find horizontal and vertical integration advantageous and are actively expanding their reach and capabilities
- Canadian telecom background may help in power electronics design

Investment thesis

Canada's opportunities are limited to niche applications combining multiple technologies and power electronics

Niche applications in power distribution for domestic consumption or export

- Niches (e.g. specialized high-power switches and sensors, integration into utility systems) still fragmented and not served by the majors
- Limited potential for long term domestic growth/GDP, as major manufacturers will compete with or acquire rapidly growing technologies

SOURCE: McKinsey Advanced Industrials Practice

GLOBALLY ATTRACTIVE

Buildings and Communities: Advanced lighting

Technology Areas Under Consideration

- Lamp, ballast/optics, luminaire, external control (including system level control, automation)
- Does not include organic light-emitting diode (OLED) and flexible LED displays
- Active power management
- Alternative lighting techniques

Other countries have a clear advantage

Market and Tech Overview

The global market for advanced lighting is large, with strong growth particularly in LEDs, driven by continuous cost reduction and regulations

LED global market expected to grow to $38B by 2020

- Driven by replacement of incandescents (voluntary and required by regulation)
- Also increased overall demand

LED technology rapidly commoditizing upstream, with some areas for innovation downstream

- Upstream chip and packaging in process of commodification and consolidation, with large cost advantages and capacity build-out in China and Taiwan
- Luminaire market fragmented but has many large players

Niche technologies are emerging downstream

- Active power management (fluorescent/LED dimming at a building-wide level)
- Non-conventional lighting (light-pipe/daylighting)

Canada's Advantage

Canadian companies may be present in niche downstream applications, but competition is high throughout all parts of the value chain

Canadian companies unlikely to be competitive in LED lighting except in niche downstream applications

- Upstream entry unlikely, as Chinese and Taiwanese making massive investments in chip manufacture with large gov't subsidies of metal-organic chemical vapour deposition (MOCVD) capacity
- Downstream applications still highly fragmented, but Canadian companies unlikely to be competitive in cost-driven manufacturing
- May be possible to enter where application requires advanced design, manufacturing optimization (e.g. quality control and scaling)
- Canada companies small compared to Chinese players

Several other gov'ts funding general lighting development

- US Department of Environment "L-Prize" for drop-in incandescent replacement spurred development

Investment thesis

Canada's opportunity is to stimulate domestic usage of LEDs, with some possibility of exporting niche products and services

Stimulate domestic luminaire growth through large-scale public LED adoption programs

- Encourage local manufacturers to take advantage of ability to work closely with Canadian contractors and gov't

Possible export of outdoor luminaires

- Chinese market is especially attractive, and gov't street light LED pilot targeting 65% penetration by 2015
- In public projects, partnering with general engineering firms more favorable as they are further downstream
- Procurement is major cost disadvantage – will likely have to do manufacturing in China, limiting Canadian jobs and GDP impact

SOURCE: McKinsey Advanced Industrials Practice

GLOBALLY ATTRACTIVE

Buildings and Communities: Energy Efficient buildings

Technology Areas Under Consideration

- Advanced windows value chain (raw materials, assembly, services)
- HVAC value chain (manufacturing, services) includes small scale CHP
- Pre-fabricated (pre-fab) EE houses

Canada could take lead in emerging market

Market and Tech Overview

The global windows and HVAC market is large and growing, with most demand in Asia, and relatively mature technologies, emerging pre-fab EE houses

Large and moderately growing demand for windows and HVAC

- $69B windows global market 2011
- $130B HVAC global market 2011
- Moderately growing demand, mostly driven by growth in Asia

Current technology is relatively mature, with some emerging innovative technologies

- Technology innovation has focused on energy efficiency
- Examples: active windows, liquid desiccants for cooling, CHP for heating

Building owners need regulations of incentives for adoption

- Market failure when building owner has to buy the EE equipment, but the renter is the one who saves on energy bills

Prefab EE houses are emerging, but the market for them is still small and immature

Canada's Advantage

Canada has a cold climate, a large window manufacturer and is a leader in net-zero building initiatives, but it is unclear if this will give it a competitive advantage over other global players

Cold climate encourages efficient building adoption
Canada manufactures windows

Canada is a leader in net-zero energy building initiatives

- Net-zero energy homes are promoted, with standards
- Canada Mortgage and Housing Corporation is sponsoring the Equilibrium Sustainable Housing Competition
- Several pilot homes for net-zero passive house
- Energy-Star qualified prefabricated homes have been introduced, including LED/Cine Reflect Lighting (CRL), heat recovery ventilation (HRV), skylights, solar tubes, insulating concrete forms (ICF) foundation, local sourced building materials and no-volatile organic compound (VOC) paints and finishes, $60-$90/square foot

Investment thesis

Canada's opportunity is to capture the domestic benefit of increased building efficiency early, with the possibility of export to global markets

Increase domestic building efficiency through adoption of efficient windows and HVAC

- Majority of residential housing is poorly insulated, with windows accounting for 10-20% of energy losses
- Active window coatings can reduce life cycle costs by 30-45% over 30 year period
- Incentives and/or regulations for adoption might address market failure

Possible export of pre-fab homes, but high labour costs in Canada suggest that this is most likely a domestic market

SOURCE: McKinsey Sustainability and Resource Productivity Practice

GLOBALLY ATTRACTIVE

Energy Intensive Industrial Processes: EE Industrial Processes

Technology Areas Under Consideration

- Energy efficient processes for a variety of industries including chemicals, steel, mining and other metals, pulp and paper, cement and agriculture

Canada could take lead in emerging market

Market and Tech Overview

Large markets with potential for both continuous improvement and disruptive innovation

Large market with moderate growth
- Industrials drive 32% of the global energy consumption today
- Moderate (1.1%p.a.) growth is expected
- Most growth in China

Current technologies are well established, with potential for process disruptions
- Multiple incremental changes using established technologies can lead to 20-30% energy savings (e.g., system integration across multiple products, minimize waste streams, manage load, power, torque and speed)
- Innovations in enhanced instrumentation, monitoring and data interpreting systems to enable real-time control

Industries are aware of disruptive technologies, but need incentive for adoption
- Examples of potentially disruptive processes:
  - Steel: remove coking process
  - Mining: convert waste to revenue products or benign materials
  - Cement: refuse derived fuels
  - Paper: new products

Canada's Advantage

Canada's has many energy-intensive industries and some small companies with innovative technologies, but there are major competitors in the US and EU

Canada has significant steel, mining and other metals, pulp and paper, cement and agriculture industry today

US and EU are the global market and technology leaders in energy efficient processes and potentially disruptive processes
- Most of the energy efficient processes are known and use US/EU technologies, some manufacturing already moving to Asia given the regional demand
- US and EU viewed as the providers of technology and equipment leaders in energy efficiency equipment and processes

Canada has some small companies with innovative technologies
- Energy consumption avoidance with motor control
- Waste reduction and optimized process control
- Real-time monitoring and control

Investment thesis

Canada's greatest opportunity is to develop process technology that directly increases the competitiveness of Canadian companies

Potential to increase competitiveness of Canadian industrial companies
- Encourage broader adoption of known energy efficient processes (e.g., through capex financing)
- Encourage R&D on disruptive processes could provider longer term cost competitiveness

Some potential to export equipment associated with new processes (if developed)
- Most companies view processes as trade secrets that they would not want to share with competitors
- It is possible to export equipment associated with new processes if developed, but there is limited industrial equipment sector in Canada today

GLOBALLY ATTRACTIVE

Energy Intensive Industrial Processes: Water

Technology Areas Under Consideration

- Engineering/Procurement/Construction (EPC) firms
- Products (pipes/pumps/valves, membranes, other filtration equipment, chemicals)
- Operation and Maintenance for Industrials and Municipalities (e.g. real-time source water monitoring and treatment efficiency)
- Commercial/Residential use (e.g., water filters/treatment for home) or small isolated communities and ships
- Infrastructure Management (e.g. pipeline condition, pipe network monitoring)

Canada could increase its global competitiveness

Market and Tech Overview

The water market is large, growing and technologically mature in many parts of the value-chain; new technologies face conservative water utilities regulation and scaling issues

Large and fast-growing global market for water

- $515B globally in 2011 equipment , services and operations
- $110B globally in equipment
- Highest growth in membranes and filtration equipment ($18B with >10% growth)
- Effective waste water processing is required for social license to operate in oil and gas industry
- Growing interest in pipeline leakage detection

R&D funding is required for new technology development

- Often little incentive to develop new technologies without regulations
- Many mature technologies already exist today, but innovations are emerging in membranes, filtration and pumps
- Unconventional oil and gas driving waste water treatment innovations

Canada's Advantage

Canada has several promising technology companies, but it has proven difficult to keep attractive technologies within Canada

Canadian companies are strongest in membranes and filtration equipment

- Cluster of water companies in Ontario

Leading technologies are developed in Canada in membranes and filtration equipment

Loss of manufacturing jobs due to foreign acquisition

Developing Electrokinetics water treatment

Investment thesis

Canada's opportunity is to grow and retain its existing strength in membrane and filtration, and attract foreign development to Canada, growing its water hub

Continue to grow existing strength around membranes and filtration equipment for both domestic and export market

- 2000+ directly employed in Ontario
- Need to help smaller start-ups scale-up: traditionally difficult given Canada's domestic market is weak

Become beach head for foreign companies that are trying to enter NA market

- Attract European players to test our NA market in Canada

Waste water treatment technology for oil and gas has some potential for export

- Potential to export for mining operations
- Potential to export for other unconventional oil and gas operations

SOURCE: McKinsey Sustainability and Resource Productivity Practice, expert interviews

GLOBALLY ATTRACTIVE

Energy Intensive Industrial Processes: Waste to Energy

Technology Areas Under Consideration

- Equipment (and associated) for converting waste to energy
- Engineering/Procurement/Construction: design of waste to energy plant
- Operations and maintenance of waste to energy plant

Canada could take lead in emerging market

Market and Tech Overview

WTE is a moderately sized market dependent on regulatory drivers, with a mix of regionally established technologies and potentially disruptive technologies on the horizon

Moderately sized market where growth depends on regulations
- $4B market in revenue 2011 (electricity+tipping fee)
- $77B in equipment market in 2014
- Potential for growth given large untapped potential, but adoption depends on tipping fees

Some established technologies today, but emerging technologies could be disruptive
- Incineration and anaerobic digestion are well developed technologies
- Plasma gasification and thermal gasification are potentially disruptive, could be 2-3 years from commercial feasibility
- Pilot projects need funding to reach commercial scale; waste utilities are conservative and require commercial demonstration

Economic attractiveness depends on regulatory environment and other risks
- Current technology only attractive given tipping fees today, which depends on the local/regional regulatory dynamics
- Some new technologies may attractive unsubsidized
- Technology risk as plasma gasification and thermal gasification technologies are still immature

Canada's Advantage

Canada has some leaders in emerging WTE technologies, but unclear whether it can become an export leader

US and Europe are the large markets today
- US and Europe are the large markets for waste to energy today given favorable tipping fees and regulatory environments
- Canada has a limited domestic market today given population size, less stringent recycling regulations and low cost of electricity

Canada can be a leader in emerging technologies
- Canada has multiple waste to energy start-ups exploring new technologies

Investment thesis

Canada's opportunity is to use new WTE technologies domestically and possibly export to US markets

Potential to export technology and equipment to US/EU (once proven at scale)
- If Canada can develop disruptive waste to energy technologies, then the equipment and technologies may be exportable to US/EU
- However, WTE in EU currently profitable because of limited land and high tipping fees, strong recycling regulations. Technology is only part of solution, and a holistic understanding of the export market is required before entering

SOURCE: McKinsey Sustainability and Resource Productivity Practice

GLOBALLY ATTRACTIVE

Transportation: CNG/LNG fleets

Technology Areas Under Consideration

- Natural gas vehicles (both liquid and compressed varieties)
- Natural gas supply (e.g. refueling stations)

Potential long term opportunity

Market and Tech Overview

CNG/LNG adoption in heavy vehicles will be driven by inexpensive natural gas in NA, but only after 2020

CNG/LNG predicted to become large part of truck fleet in US
- Shift to natural gas heavy vehicles in US (1.0 QBTU in 2020, 3.0 QBTU in 2050) due to low NG prices[1]
- CNG/LNG do not gain appreciable share in light vehicles

Refueling infrastructure is not in place for mass adoption
- CNG being used in short-range fleets
- LNG favored for long-haul fleets where longer ranges and faster refueling are required and higher capital expense is acceptable
- Lack of refueling infrastructure prevents widespread adoption

Canada's Advantage

Canada has large natural gas deposits and major players in NG engines and vehicle manufacturing

Canada has large natural gas deposits
- Located in Western Canada and connected to US gas networks
- Price disadvantaged export to US due to transportation costs

Canada is developing natural gas truck engine technology

Canada supplies the global auto market

Natural gas supplies have historically been volatile
- Low of 2 $US/million Btu (MMBTU) to high of 14 $US/MMBTU in last ten years, with high sensitivity to disruptions across continent (e.g., Hurricanes Katrina and Rita) may dissuade long term investment
- Seasonal swings partially buffered by storage capacity in Alberta and Ontario
- Canada's demand is 1/10th, so will be subject largely to US trends
- CNG vehicle adoption tried in past but unsuccessful

Investment thesis

Canada has an opportunity for long-term development of a CNG/LNG truck fleet in NA

Cost benefit from using natural gas as transportation and industrial fuel/feedstock
- Canadian natural gas deposits incur higher costs to export to US markets, but have advantage in domestic markets
- Natural gas is less costly to use than diesel

Export natural gas engines and vehicles to US
- US market forecasted to have strong demand for natural gas in heavy vehicles

1 McKinsey Global Energy Perspective Model

SOURCE: McKinsey Automotive Practice

GLOBALLY ATTRACTIVE

Transportation: Next generation automobiles

Technology Areas Under Consideration

- EV drivetrain (batteries, power electronics, motors), body (lightweighting) and other components
- Fuel-efficient vehicle drivetrain (advanced engine technologies, braking/regeneration, storage)
- EV recharging network/infrastructure
- Not included are fuel cell, diesel , CNG/LNG, liquefied petroleum gas (LPG)

Canada could increase its global competitiveness

Market and Tech Overview

The next generation automobile market is large and continuously evolving, with improvements in internal combustion engine (ICE) and EV technologies driving efficiency and cost gains

ICE will continue to be in demand through 2020, with mass adoption of EV through 2050
- In 2030, 60M gasoline and 22M PHEV
- In 2050, mix will shift to 14M Gasoline and 87M PHEV, with battery electric vehicle (BEV) and fuel cell vehicle (FCV) adoption in China, driven electricity prices

EV and ICE technology continuously evolving
- Active research into improved battery, power electronic, motor and materials technologies
- Some disruptive technologies (e.g. SiC) on the horizon
- Large suppliers with established relationships favored
- Recharging tech mostly waiting for standardization

Rare earths are a long term play with technological risks
- Most projects require significant capital investment and will not come on-line for 7-10 years or more
- Significant environmental issues , including thorium by-products, tailings management, perception of cyanide and arsenic

Canada's Advantage

Canada supplies global markets and has significant related activity in startup and supplier companies, and a potentially exploitable natural resource

Canada is a global auto supplier with major EV and auto parts contacts in North America and EU/Japan

Canada has robust startup activity in EV technologies, but will need to compete with other major suppliers and major OEMs

Canada has a large mining industry and abundant rare-earth deposits
- 500ktons of rare earths worth estimated $296B CDN (Alberta Black Shale Deposit) [1]
- Proposal to use bioleaching instead of cyanide/arsenic
- Active exploration in several other areas with proposals for extraction in 2015-2020 timeframe

Investment thesis

Canada's opportunity in the short term will be to maintain and expand its position as a global auto manufacturer and technology player, and seek ways to increase its supplier advantage in the long term

Maintain and expand Canadian auto supplier's positions as technology player in EV

Canada could further increase its supplier advantage by becoming a low-cost producer of rare earths used in magnets/polishing
- Most rare earth used in EV motor magnets and polishing
- Demand for rare earths to continue growing (11% p.a.) through 2015 with China as major consumer (70%)

1 Canadian Chamber of Commerce Economic Policy Series, April 2012

SOURCE: McKinsey Automotive, Global Energy and Materials (GEM) Practices

STRATEGICALLY IMPORTANT FOR CANADA

Transportation: Advanced Trains and Aircraft

Technology Areas Under Consideration

- Electric rail and urban transit (including hardware, controls and services, lightweight materials and reduced rolling resistance)
- Advanced airframe and systems
- Engine design
- Alternative fuels

Canada could increase its global competitiveness

Market and Tech Overview

Worldwide train and aircraft markets are large and moderately growing, with some niche technology development

Large and moderately growing demand for trains and aircraft
- Rapid growth in electric rolling stock to $48B in 2020
- Least fragmented (most promising) segments are high-speed and urban passenger rail
- 12,800 aircraft of all types delivered through 2030 with most growth in 60-99 seat segment
- Focus on fuel efficiency

Current technology is relatively mature, with some niche development spaces
- Some opportunity in electric trains controls optimization and energy management
- Continuing focus on fuel efficiency including engine technology and lightweighting
- Interest and investment into alternative, non-fossil-fuel based sources of aircraft fuel

Rail electrification is dependent on regulation and public funding

Disruptive fuel efficient aircraft technologies are immature

Canada's Advantage

Canada has a significant aerospace sector, including several aerospace suppliers and OEMs that are located in Canada

Investment thesis

Canada can maintain its large anchor companies by encouraging continuing innovation and domestic manufacturing growth

Aerospace companies bring jobs and export value to Canada

SOURCE: McKinsey Aerospace Practice

STRATEGICALLY IMPORTANT FOR CANADA

Transportation: Fuel Cell Systems

Technology Areas Under Consideration

- Hydrogen fuel cells for vehicles
- Refueling infrastructure
- Integration of Fuel cells with grid-scale storage

Potential long term opportunity

Market and Tech Overview

The hydrogen fuel cell market is potentially large after 2020-2030 but until faces significant technology and adoption barriers in the interim

Hydrogen fuel cells seen as long term technology for vehicles

- History of unfulfilled promises (e.g. hydrogen economy support)
  - No major government commitments, niche areas in California, Iceland

Fuel cells depend on carbon regulation

- 10 gCO2/km: <5% market share by 2020, 30% market share by 2030
- 95 gCO2/km: 0% market share in 2020, <2% market share by 2030

Fuel cells compete with batteries for small vehicles, and biofuels for large vehicles

- Many experts say battery EV are likely to see commercialization first, due to rapid drop of lithium-ion battery prices
- Hydrogen vehicles also poses significant challenges for the OEM as they will now require 4 engines in parallel

Fuel cells in grid storage are promising but still have unproven economics compared to other forms of energy storage

Canada's Advantage

Canada has invested in fuel cell manufacturing and has developed some expertise – thus, already establishing Canada as a fuel cell manufacturer

Major R&D in Canada

Abundant natural gas leads to interim (non-renewable) hydrogen supply through reforming

- Some CDN expertise in both reforming and electrolysis

Investment thesis

Canada's opportunity is limited to continuing to fund long-term fuel-cell R&D and commercialization

Maintain R&D, with appreciable cost reduction requirements for continued funding

- Focus on platinum alternatives, synergies with near-term EV market and infrastructure including grid-storage